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Determination of Importance Evaluation Interim Change Notice Cover Sheet

QA: QA

1. DIE Title	Document Control Use Only
Determination of Importance Evaluation for Exploratory Studies Facility (ESF) Subsurface Testing Activities	
2. Document Identifier (DI) Number (include revision number)	
BAB000000-01717-2200-00011 REV 03 ~~A~~ / ICN 01	

3. Description of Interim Change (include list of pages involved in this ICN)

Added After-the-Fact Evaluation for Viton Packer HF Generation.
Changed some reference callouts in document to new format
Added new references in support of After-the-Fact evaluation and Section 13.2.46 changes
Added quantity and concentration limits to Alcove 8 TFM list

Prepared By

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21. Remarks

PA-Technical Review of pages 93-96 Performed by Rich Metcalf.

DIE/SPPE
Revision Record

Complete only applicable items.

1. Title	2. Eval. Type
Determination of Importance Evaluation for Exploratory Studies Facility (ESF) Subsurface Testing Activities	☑ DIE ☐ SPPE

3. DI Number (include revision number)
BAB000000-01717-2200-00011 REV 03/ ICN 01

4. Rev/ ICN No.	5. Date	6. Description of Revision/ICN
00	10/29/97	Initial Issue
01	08/11/98	Revision 01 of this DIE evaluated tracer testing in Topopah Spring (TS) Loop alcove slot cuts and niches (including the construction of the alcove slot cuts), moisture monitoring stations, Alcove #1 and #7 surface infiltration testing (including new tracers for Alcove #1 testing), Geomechanics of rock mass studies, active seismic mapping experiments and geophone installations, closure(completion activities associated with the single heater test in Alcove #5, and ECRB Cross Drift testing. Interim Change Notices (ICNs) 01, 02, and 03 to Revision 00 of this DIE were incorporated. Attachment II was updated to include new tracers, fluids, and materials (TFMs) associated with the above activities. Two DIEs (DIE for Infiltration Testing into Alcoves #1 and #7 and Subsurface Geomechanics of Rock Mass Studies - BABEAF000-01717-2200-00012 Rev 00 and DIE for Niche and Alcoves Slot Cut Tracer Testing - BABEAF000-01717-2200-MI4 Rev 00) were incorporated into this Revision and were superseded in total. The Subsurface testing activities associated with the DIE for ESF and Surface-Based Active Seismic Mapping Experiments - BA0000000-01717-2200-00009 Rev 01 (Reference 14.126) were included in this DIE, but the Seismic Mapping DIE remained active until the Surface-Based portions were incorporated into the DIE for Surface-Based Testing Activities or similar DIE. Five new Quality Assurance (QA) controls were added. Updated and added various references. Made various editorial changes throughout.
02	06/01/00	Revision 02 of this DIE addressed the planned testing in the ECRB Cross Drift Cross Over Alcove (Alcove #8) and Niches #5 and #6; systematic drilling and testing planned in sections of the ECRB; installation of bulkheads in the ECRB Cross Drift at approximate ECRB Stations 17+63, 25+03, and the possible addition of a third bulkhead beyond 25+03; and several new and revised Subsurface ESF testing activities. Eliminated evaluation of Mining Methods and Air Quality and Ventilation discussions that have been removed from the Construction Monitoring Field Work Package (FWP). Replaced air quality and ventilation discussions with Radiological Monitoring discussions. Added discussions of planned laser strain monitoring of tunnel stability and water inclusion testing. Coordination of testing activities by the Test Coordination Office TCO) was emphasized in Section 13.2.42. Previous discussion of construction related activities and associated controls related to TS Loop niches and alcove slot cuts has been incorporated into Reference 14.1 and, as such, been eliminated from this DIE. The Attachment II TFM list was updated and additional groups were added to cover the ECRB Alcove, Niche, and Systematic Drilling testing activities. Revision 02 also incorporated and superseded ICNs 01 and 02 to Revision 01 of this DIE. ICN 01 addressed the addition of new boreholes in the TS Loop to validate Chlorine-36 testing and an update to the TFM list in Attachment II.

Complete only applicable items

3. DI Number (include revision number)
BAB000000-01717-2200-00011 REV 03/ ICN 01

4. Rev/ ICN No.	5. Date	6. Description of Revision/ICN
03	09/21/01	Revision 03 of this DIE updates water loss limits and updates and expands earlier limits on use of fluorobenzoic acids as tracers in the ECRB Alcove # 8 /Niche#3 based on new information. Planned Cross-Drift Thermal Testing in ECRB Alcove # 10 is addressed in this DIE regarding construction controls, testing setups, and testing controls. Significant editorial changes were made to the reference section and throughout the document to be compliant with the Ensure Defensible Documents initiative. Changed Safety Assurance (SA) Department back from Systems Engineering (SE) teamresponsible for DIEs (SE DIE team) to Safety Assurance (SA) Department throughout. Updated Attachment II of the DIE with newly approved TFM's . Discussion evaluating thepreliminary results of water injection in the back of Alcove #8 to determine penetration between Alcove #8 and Niche #3 has been added to this DIE. Deleted Requirement 17 from Rev 02 of this DIE and added site specific water controls for Alcove #8/Niche#3 to Requirement 3 as 3c. Added discussion of geotechnical testing in the TS Loop and the ECRB.
03/ICN1	5/10/02	Added After-the-Fact Evaluation including references for Viton Packer HF Generation Changed reference for Liu Predictive Model for Alcove 8 infiltration test Added quantity and concentration limits to Alcove # 8 TFM list Modified wording in Section 11.1.5 to clarify control limits

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TABLES

1. PURPOSE

This Determination of Importance Evaluation (DIE) applies to the Subsurface Exploratory Studies Facility (ESF), encompassing the Topopah Spring (TS) Loop from Station 0+00 meters (m) at the North Portal to breakthrough at the South Portal (approximately 78+77 m), and ancillary test and operation support areas including the Enhanced Characterization of the Repository Block (ECRB) Cross Drift. This evaluation applies specifically to site characterization testing activities ongoing and planned in the Subsurface ESF. ESF site characterization activities are being performed to obtain the information necessary to determine whether the Yucca Mountain Site is suitable as a geologic repository for spent nuclear fuel and high-level radioactive waste. A more detailed description of these testing activities is provided in Section 6 of this DIE. Generally, the construction and operation of excavations associated with these testing activities are evaluated in the DIE for the Subsurface ESF (CRWMS M&O 1999a) and the DIE for the ESF ECRB Cross Drift (CRWMS M&O 2000a).

The scope of this DIE also entails the proposed Unsaturated Zone (UZ) Transport Test at Busted Butte. Although, not a part of the TS Loop or ECRB Cross Drift, the associated testing activities are Subsurface testing activities. Busted Butte is located to the south south-east of the TS Loop and is outside the Conceptual Controlled Area Boundary (CCAB). These activities provide access to the Calico Hills (CH) geologic structure. In the case of Busted Butte, construction and operation of excavations are evaluated herein (since this activity was not previously evaluated in CRWMS M&O 1999a).

The objectives of this DIE are to determine whether Subsurface ESF testing, and associated activities, could potentially impact site characterization testing and/or the waste isolation capabilities of the site. Controls needed to limit any potential impacts are identified in Section 13. The validity and veracity of the individual tests, including data collection, are the responsibility of the assigned Principal Investigator(s) (PIs) and are not evaluated in this DIE.

This DIE focuses on integrating and compiling the evaluations of previous DIEs which were prepared for various ESF subsurface testing activities, including the use of temporary items currently located or being developed for these testing activities (see Table 1.1), and to provide a bounding evaluation for potential future ESF subsurface testing activities that are sufficiently similar to the generic testing activities addressed herein. Subsurface testing activities items/facilities evaluated herein include: ongoing and planned testing in the TS Loop, alcoves, and niches, planned testing in the ECRB Starter Tunnel, borehole drilling and workover, and tracers, fluids, and materials (TFM) usage. Detailed identification of individual testing items/facilities and generic descriptions for subsurface-testing-related activities are provided in Section 6.

The conclusions and requirements of this DIE conservatively bound the conclusions and requirements of previously approved DIEs for the ESF subsurface testing activities addressed herein, based on conservative engineering judgement and on concurrence with this DIE (via a formal review process) by the originating and reviewing organizations of the previously approved evaluations. Hence, this DIE supersedes the following DIEs listed in Table 1.1.

Table 1.1. Superseded DIEs

Type of Document	Title	Document Identifier	Date
DIE	DIE for ESF and Surface-Based Active Seismic Mapping Experiments	BA0000000-01717-2200-00009 REV 01/ ICN 01	5/14/98; 6/4/98
DIE	DIE for the Use of Additional Water in Alcove #1 Infiltration Testing	BAB000000-01717-2200-00019 REV 00	11/1/99
DIE	DIE for Perched Water Testing	BAB000000-01717-2200-00109 REV 01	10/21/95
DIE	DIE for Consolidated Sampling	BAB000000-01717-2200-00110 REV 01	10/21/95
DIE	DIE for Geologic Mapping	BAB000000-01717-2200-00112 REV 01	10/21/95
DIE	DIE for Hydrochemistry Tests, Radial Borehole Tests, and Hydrologic Properties of Major Faults Encountered in the ESF	BAB000000-01717-2200-00146 REV 02	9/13/96
DIE	DIE for the Moisture Studies in the ESF	BAB000000-01717-2200-00151 REV 00	6/14/96
DIE	DIE for Laser Strain Measurement/ Deformation Monitoring Testing	BABDC0000-01717-2200-00001 REV 00	11/29/99
DIE	DIE for the Exploratory Studies Facility Alcove #2 Exhibit Area	BABEA0000-01717-2200-00001 REV 00	5/27/97
DIE	DIE for Phase I Testing in the TS Main Drift Thermal Testing Facility	BABEAF000-01717-2200-00003 REV 01	11/14/96
DIE	DIE for Hydraulic Fracture Testing in the Exploratory Studies Facility Thermal Testing Facility	BABEAF000-01717-2200-00004 REV 00	9/17/96
DIE	DIE for Testing in the ESF Thermal Testing Facility Heated Drift	BABEAF000-01717-2200-00006 REV 01	12/20/96
DIE	DIE for the ESF Drift-Scale Flux and Niche Study	BABEAF000-01717-2200-00007 REV 01	4/1/96
DIE	DIE for Confirmation Drilling in the Exploratory Studies Facility	BABEAF000-01717-2200-00008 REV 00	2/18/97
DIE	DIE for Ground Support in the Vicinity of Fault Zones	BABEAF000-01717-2200-00009 REV 00	5/16/97
DIE	DIE for Infiltration Testing into Alcoves #1 and #7 and Subsurface Geomechanics of Rock Mass Studies	BABEAF000-01717-2200-00012 REV 00	12/19/97
DIE	DIE for Niche and Alcoves Slot Cut Tracer Testing	BABEAF000-01717-2200-00014 REV 00	6/29/98

Revision 01 of this DIE addressed several new and revised Subsurface ESF testing activities. These included tracer testing in alcove slot cuts and niches, moisture monitoring stations, Alcove #1 and #7 surface infiltration testing (including new tracers for Alcove #1 testing), geomechanics of rock mass studies, active seismic mapping experiments and geophone installations, closure/completion activities associated with the single heater test in Alcove #5, and ECRB Cross Drift testing. Revision 01 also incorporated Interim Change Notices (ICNs) 01, 02, and 03 to Revision 00 of this DIE. ICN 01 addressed the planned testing activities in the TS Main Drift at the ECRB Cross Drift cross over point and updated the TFM list in Attachment II. ICN 02 expanded the TFM list to include additional TFMs required for UZ Transport Testing at Busted Butte. ICN 03 expanded the use of concrete on the Alcove #5 invert for safety purposes. The two DIEs added to Table 1.1 above (BABEAF000-01717-2200-00012 REV 00 and BABEAF000-01717-2200-00014 REV 00) have been incorporated in this revision and are superseded in total. The subsurface testing activities associated with the DIE for ESF and Surface-Based Active Seismic Mapping Experiments, BA0000000-01717-2200-00009 REV 01 are included in this DIE (this DIE is included in Table 1.1 for completeness as noted below).

Revision 02 of this DIE addressed the planned testing in the ECRB Cross Drift Cross Over Alcove (Alcove #8) and Niches #5 and #6; systematic drilling and testing planned in sections of the ECRB; installation of bulkheads in the ECRB Cross Drift at approximate ECRB Stations 17+63, 25+03, and the possible addition of a third bulkhead beyond 25+03; and several new and revised Subsurface ESF testing activities. Eliminated evaluation of Mining Methods and Air Quality and Ventilation discussions that have been removed from the Construction Monitoring Field Work Package (FWP). Replaced air quality and ventilation discussions with Radiological Monitoring discussions. Added discussions of planned laser strain monitoring of tunnel stability and water inclusion testing. Coordination of testing activities by the Test Coordination Office (TCO) was emphasized in Section 13.2.42. Previous discussion of construction related activities and associated controls related to TS Loop niches and alcove slot cuts has been incorporated into CRWMS M&O (1999a) and, as such, been eliminated from this DIE. The Attachment II TFM list was updated and additional groups were added to cover the ECRB Alcove, Niche, and Systematic Drilling testing activities. Revision 02 also incorporated and superseded ICNs 01 and 02 to Revision 01 of this DIE. ICN 01 addressed the addition of new boreholes in the TS Loop to validate Chlorine-36 testing and an update to the TFM list in Attachment II. ICN 02 addressed the addition of new boreholes in the ECRB Cross Drift for air-permeability and blast effects testing near Niche #5, supplemental information associated with the Chlorine-36 validation testing, and added additional items to the TFM list in Attachment II. The three DIEs added to Table 1.1 above (BA0000000-01717-2200-00009 REV 01/ICN 01 [noted in Revision 1 discussion above], BAB000000-01717-2200-00019 REV 00, and BABDC0000-01717-2200-00001 REV 00) have been incorporated in this revision and are superseded in total. Changed Safety Assurance (SA) Department to System Engineering (SE) team responsible for DIEs (SE DIE team) throughout. Significant editorial changes were made to the reference section and throughout the document to be compliant with the Ensure Defensible Documents initiative. Change bars were only used to indicate new references in the reference section, format changes were not change barred. Revision 03 of this DIE changes the Systems Engineering (SE) team back to the Safety Assurance (SA) team responsible for DIEs throughout. Change bars have been used to indicate editorial changes, new TFM approvals, new text, and new (or updated) references in the reference section. This DIE updates Alcove #8 water loss limits and updates and expands earlier limits on use of fluorobenzoic acids as tracers in the ECRB Alcove #8/Niche #3 based on new information. In addition this Revision 03 considers Alcove #10 testing.

2. QUALITY ASSURANCE

This evaluation was prepared using Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) implementing line procedure Nevada Line Procedure NLP-2-0, *Determination of Importance Evaluations,* subject to the requirements of the United States Department of Energy (DOE) Office of Civilian Radioactive Waste Management Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program (DOE 2000). A Technical Work Plan has been prepared for those activities implemented by NLP-2-0 in accordance with AP-2.21Q, *Quality Determination and Planning For Scientific Engineering and Regulatory Compliance Activities*, to evaluate activities described herein in terms of their being subject to QARD requirements (CRWMS M&O 2000e). This establishes the responsibilities and processes for this DIE. This DIE is quality-affecting because it establishes the applicability of the Quality Assurance (QA) program to the evaluated ESF subsurface testing activities with specific regard to potential impact to site characterization data, the waste isolation capabilities of a potential geologic repository at the Yucca Mountain site, and other permanent, Q-List (YMP 1998a) items (which have been classified QA-1, QA-2, and QA-5, including natural barriers) that have been constructed or installed at the Yucca Mountain site. Pursuant to the requirements of Title 10 of the Code of Federal Regulations, Part 60 (10 CFR 60), Section 15(c)(1), QA controls for minimizing, to the extent practical, any potential for impacts (as identified herein) to permanent, classified items, including potential impacts associated with the use of temporary items, are also established by this DIE.

3. METHODOLOGY

This evaluation was performed in accordance with procedure NLP-2-0. This is a Category-III DIE since it addresses field activities that are potentially significant with respect to the Q-List (YMP 1998a) items and site characterization data and, as a result of consolidating all Subsurface ESF testing activities into a single, stand alone DIE, will not have an applicable, active category III DIE or analogous precedent. The DIE is prepared by: (1) reviewing the best available design information (as discussed in this section) related to surface/subsurface construction, operation, maintenance, and reclamation activities associated with the ESF Subsurface Testing items/facilities; (2) evaluating the potential of these items and activities to affect Q-List (YMP 1998a) items and site characterization testing; and (3) establishing QA controls where necessary to minimize potential impacts on Q-List (YMP 1998a) items and site characterization activities to the extent practical.

For the ESF Subsurface Testing sites identified in Section 6 of this DIE, many of the activities evaluated herein were completed before the approval of this DIE. Hence, the QA controls developed in Section 13 are intended to be applied commensurate with the current status of the ESF Subsurface Testing site.

The best available information related to ESF Subsurface Testing items/facility construction, operation, maintenance, reclamation, and testing activities includes but is not limited to: M&O preliminary approved design documents and revisions to construction drawings and specifications for subsurface accommodations, FWPs, Testing Study Plans, TCO/PI criteria letters, the Yucca Mountain Site Characterization Project (YMP) Site Atlas (DOE 1997), and applicable e-mails. In cases where inputs from these documents provide critical characteristics that could potentially impact the conclusions and derived requirements of this evaluation, specific reference citations are provided in the text.

After approval of this DIE, implementing documents (e.g., FWPs, design specifications, and design drawings) will be reviewed by the SA DIE team. These reviews are conducted to: (1) ensure that the original basis for the evaluation (i.e., best available design information) adequately bounds the final scope of activities to be conducted in the ECRB Cross Drift, and (2) verify that any applicable DIE requirements have been properly integrated into the implementing documents.

4. ASSUMPTIONS

4.1 It is assumed throughout this evaluation, unless specifically stated otherwise, that the minimum offset from the closest waste package emplacement area is 37 m for the TS Loop (including associated excavations) (CRWMS M&O 1995a) and Phase I (Stations 0+26.4 m to 7+73 m) of the ECRB Cross Drift (including associated excavations) and 15 m for Phase II (Stations 7+73 m to the end of the ECRB Cross Drift [approximate Station 26+81 m]) of the ECRB Cross Drift (including associated excavations) (CRWMS M&O 1997a) to establish bounding conditions for this analysis (as stated in Section 11.1.4).

4.2 In establishing the boundaries for the DIE, it is assumed that construction and other activities associated with Tunnel Boring Machine (TBM) operation, utilities installation, and support for TBM operation for construction of the ECRB Cross Drift will be in accordance with the ESF Design specifications and drawings, which implement applicable requirements of the Exploratory Studies Facility Design Requirements document (ESFDR) (YMP 1997a).

4.3 Testing support accommodations (i.e., cable runs, standard power, lighting, compressed air, ventilation, communications, Data Collection System [DCS] connection, etc.) critical to the conduct of specific tests are addressed in the FWPs developed for those tests. The DCS is supplied by the Natural Environment Program Operations (NEPO) (formerly Site Evaluation Program Operations) and is controlled under the appropriate National Laboratory QA procedures. The FWPs will also address access needed to support the testing operations as soon as practical after testing equipment is installed, or testing space is constructed. This assumption further clarifies the scope of the DIE (as stated in Section 1 and throughout the evaluation) with respect to testing activities.

4.4 The TFMs to be used in the Subsurface ESF will be those for which data (e.g., Material Safety Data Sheets [MSDSs]) have been provided and reviewed (Attachment II). TFMs that have not yet been reviewed will be evaluated in accordance with the project TFM procedure (Yucca Mountain Administrative Procedure [AP] AP-2.17Q, *Tracers, Fluids, and Materials Data Reporting and Management*). It is assumed that the MSDS or other data source recommended procedures will be followed for use, storage, handling, ventilation, spills and leaks, and personnel safety. Temporary items and materials used for the construction, operation, maintenance, and reclamation of Subsurface ESF facilities and equipment used for the conduct of testing activities that are not permanently emplaced or committed to the Subsurface ESF environment or specifically controlled by requirements contained in this DIE are exempted from the installation and removal reporting requirements contained in AP-2.17Q. This assumption establishes the scope for the DIE with respect to TFMs and is based on the ESFDR (YMP 1997a) and AP-2.17Q. (This assumption is used throughout this DIE.)

4.5 Based on the TFM procedure (AP-2.17Q), it is assumed that water used for fire suppression and control will be treated as a significant spill.

5. COMPUTER CALCULATIONS

No analytical computer programs have been used directly in the preparation of this document. Procedure AP-SI.1Q does not apply in that there are no software programs used in this DIE to manipulate data or information nor is there data or information retained for this DIE. However, computer programs have been used in some of the referenced documents that form the basis of some of the results presented in this document. Detailed discussions of these computer calculations, including their treatment under the QA Program, are provided in the referenced documents.

6. DESCRIPTION OF ITEMS/ACTIVITIES

6.1 GEOLOGIC MAPPING

Geologic mapping of the ESF is conducted to document lithologic and fracture variability throughout the underground excavations, to investigate structural features, and to provide siting data to confirm (or modify) planned test locations within the underground ESF. FWP-ESF-96-010 (YMP 2000a) provides a description of geologic mapping activities.

Typical geologic mapping activities are categorized by several tasks. Exposed rock surfaces in the ESF are photographed. Detail and line surveys are performed continuously along one rib of each drift or ramp. Detail and line surveys consist of recording the characteristics of fractures, geologic discontinuities, or other features which intersect a datum line. Regular sampling of the wall rock and fracture infilling are performed concurrent with the mapping process. Typically, the constructor cleans the walls using a compressed air/water mist. Law (1998) describes the use of a low-flow pressure washer in the ECRB Cross Drift. This pressure washer has a constrictive nozzle aperture that applies only construction water (i.e., not mixed with air). The PI may operate additional air/mist equipment as necessary to further clean ESF surfaces. Lithium Bromide (LiBr) is the approved tracer for use in this air/water mist mixture.

6.2 CONSOLIDATED SAMPLING

Consolidated sampling is conducted in the ESF in support of site characterization activities, as described in FWP-ESF-96-009 (YMP 2000b). The purpose of the sampling program is to collect samples in the ESF for a variety of hydrologic, geologic, mechanical, and chemical tests, including Chlorine-36 studies discussed in Section 6.10. The method used to collect samples is generally by hand using a hammer and chisel. Alternate methods of sample collection are also identified such as using hydraulic splitters and drilling core samples. Sample locations are generally approved by the responsible PI before the sampling activity. Hazardous mineral assessments of rock samples and fluid inclusion testing samples will be taken for off-site analysis. Other non-intrusive samples are also taken periodically (e.g., air and mold samples) for off-site analysis.

6.3 PERCHED-WATER TESTING

Perched-water testing is planned as a contingency test and is conducted when/if perched water is encountered. FWP-ESF-96-011 (YMP 1997b) provides a description of the perched-water testing activities. The purpose of this test is to detect the occurrence of perched water, delineate its lateral and vertical extent, identify perching mechanism(s), and collect samples of the perched-water for chemical analyses. The form and duration of the testing is dependent upon the nature of any encountered perched water. It should be noted that during excavation of the TS Loop no perched water was encountered.

If perched water is encountered during subsequent excavation, one or more small-diameter boreholes may be drilled to enhance drainage, facilitate collection of water samples, and allow flow and/or pressure measurements to be made. The borehole(s) may be instrumented for long-term testing and monitoring to obtain data on hydraulic pressure over time. Periodic water sampling may be required from perched-water boreholes. Sulfur Hexafluoride (SF_6) and LiBr are the tracers identified for use in this test. (YMP 1997b)

6.4 HYDROCHEMISTRY TESTS

Hydrochemistry tests determine the chemical composition, reactive mechanisms, and age of water and gas in pores, fractures, and perched-water zones within the unsaturated tuffs accessible from the ESF and/or affiliated boreholes. The ESF provides access for the collection of gas, rock, and fracture-water samples. Hydrochemistry tests are generally conducted in association with other testing such as the radial borehole tests and hydrologic properties testing of major faults. Hydrochemistry tests are described in FWP-ESF-96-008 (YMP 1996a).

6.5 RADIAL BOREHOLE TESTS

Radial borehole tests investigate vertical and lateral movement of fluids (i.e., gas and water) within individual hydrogeologic units and across hydrogeologic unit's contacts (e.g., Tiva Canyon welded unit [TCw]-Paintbrush Tuff nonwelded unit [PTn] and PTn-Topopah Spring [TSw] contacts). Single and cross-hole tests are conducted to determine *in situ* air permeability. Radial borehole tests are described in FWP-ESF-96-007 (YMP 1996b). Boreholes are typically dry cored and extend for nominally 30 m. Gaseous tracer injection tests are also conducted. SF_6 and/or SUVA-COLD MP® (tetra fluoroethane) tracer gases are used when drilling the boreholes. Borehole geophysical and downhole video logging is conducted after boreholes are drilled. After initial testing and instrumentation, long-term monitoring may take place for several years.

The water-injection testing using a 100 liter per minute, 100 kiloPascal pressure water injection system (as discussed in YMP 1996b) has not been evaluated in this DIE and is specifically excluded from the scope of this DIE. This activity requires additional evaluation by the SA DIE team before the conduct of this test.

6.6 HYDROLOGIC PROPERTIES OF MAJOR FAULTS ENCOUNTERED IN THE ESF

Hydrologic properties testing of major faults encountered in the ESF provides hydrologic information to quantify hydrologic properties of large structural features, such as faults, by testing on a smaller scale at selected locations accessible from the alcoves, ramps, and/or drifts in the ESF. The data collected is used in a matrix hydrologic property database that models matrix flux in Yucca Mountain under varieties of upper-boundary conditions which simulate possible climatic conditions. FWP-ESF-96-006 (YMP 1997c) describes and governs the conduct of hydrologic properties testing of major faults encountered in the ESF.

The hydrologic properties testing includes: (1) measuring pneumatic and hydraulic permeability, porosity, and anisotropy of major faults along with associated fault zones; (2) monitoring flow of gas, water, and vapor in major faults of the UZ; and (3) conducting tracer tests to estimate the tortuosity and effective porosity of faults and their associated fault zones. (YMP 1997c)

Hydrologic properties testing typically includes dry drilling activities, tracer gas injection, surveying of boreholes, and instrumentation and monitoring of the boreholes. The tracer planned for use is SF_6. However, SUVA-COLD MP® (tetra fluoroethane) is also permitted per YMP (1997c).

6.7 SEISMIC MONITORING

Seismic monitoring is primarily a Surface-Based Testing activity and is addressed in CRWMS M&O (2000b); however, certain portions of the activities described in FWP-SB-97-007 (YMP 1998b) occur in the Subsurface ESF. The purpose of the seismic monitoring program is to observe and track naturally occurring seismic activity within a grid of seismic stations surrounding and including Yucca Mountain. The program includes the installation and maintenance of these seismic station instruments as well as the capability to deploy portable instruments at multiple locations for monitoring seismic aftershocks. A strong motion seismic station is currently installed at the end of the Thermomechanical Alcove (TMA) Extension in Alcove #5.

A network of geophone receivers has also been installed in the Subsurface ESF. Per Finnegan (1998a, 1998b, 1998c), the array of geophones extends from roughly TS Main Drift Station 26+50 m to Station 60+25 m. The geophones are spaced at approximately 15-m intervals. The activity includes the wet-drilling of nominally six-inch-deep boreholes approximately one meter above the invert on the right rib. Three-inch vertical geophones are installed in each borehole along with a small quantity of Wil-X cement around the geophones. Additional seismic equipment may be added to the Subsurface ESF later, should local seismic activity dictate.

The seismic monitoring activity also includes active seismic mapping experiments. One such experiment was described in Finnegan (1998a) and included the drilling of 2 approximately 3-m deep boreholes, with an approximate 2.25-inch diameter, in the left rib of the TS North Ramp within a variance of approximately 30 m around Station 20+10 m. These boreholes were spaced at about two-meter intervals along the TS North Ramp. Approximately 10 feet of 100-grain Ensign-Bickford PRIMACORD detonating cord was loaded at the maximum depth of each borehole. Detonation of this explosive provides the seismic source. After the explosive is loaded, the boreholes are packed off with an approved stemming material. Packing off the boreholes is necessary to ensure the required seismic wave propagation. Ensign-Bickford PRIMADET Non-Electric Delay Detonators (MS Series), or an equivalent detonator were used to detonate the explosives.

Three instrumentation boreholes, with an approximate 2.25-inch diameter, were also drilled in the left rib of the TS Main Drift within a variance of approximately 30 m around Station 39+60 m. The instrumentation boreholes were spaced at about two-meter intervals along the TS Main Drift. Each instrument borehole was drilled to a unique nominal depth—one at one-half meter, one at one meter, and one at two meter. Geophones were loaded at the maximum depths of these boreholes for monitoring the explosions. Additional wall-mounted geophones were also to be attached to the left rib of the TS Main Drift within a variance of approximately 30 m around Station 39+60 m. The geophones were attached to the host rock with an approved epoxy material. Vibro-seismic trucks were also driven along established Yucca Mountain roads for the purpose of inducing seismic readings in the aforementioned geophones located in the ESF, which is bounded by CRWMS M&O (2000b).

Mitchell (2000a) describes a seismic monitoring activity associated with a surface Waste Handling Building geotechnical testing study. In this activity, a series of up to six HQ sized boreholes, approximately three meters deep, will be drilled into the right rib of the North Ramp between Alcoves #2 and #3. These boreholes will be used to install temporary seismological instrumentation.

6.8 BOREHOLE WIRELINE MEASUREMENTS

Borehole wireline measurements are performed on numerous Subsurface ESF boreholes and coreholes. FWP-ESF-96-013 (YMP 1999a) provides a generic description of the activities involved in these measurements. The types of measurements performed include borehole video logging, caliper measurements of the borehole diameters, gamma ray surveys of background radiation, neutron surveys for porosity and saturation levels, and electron bulk density measurements. Borehole wireline measurements support other activities such as construction monitoring, thermal testing, moisture studies, hydrologic properties, hydrochemistry test, and radial borehole tests.

6.9 CONSTRUCTION AND RADIOLOGICAL MONITORING

Construction monitoring studies are designed to provide data that will be used to assess potential repository performance and support the rock mass constitutive models developed for predicting the mechanical behavior of the repository-sized openings. FWP-ESF-96-002 (YMP 1999b) provides a description of the three primary activities described below. FWP-ESF-99-001 (YMP 1999c) provides a description of a long-term deformation monitoring study being performed in the TS South Ramp. FWP-ESF-98-001 (YMP 1999d) provides a description of radiological monitoring activities described below.

6.9.1 Access Convergence Testing

The objectives of the access convergence tests are to monitor rock-mass deformation around the accesses and to measure *in situ* stress. Rock-mass deformation around the access ramp or drift are monitored at measurement stations using multiple-point borehole extensometers (MPBXs) and single-point borehole extensometers placed at the crown and springline of the opening. Diametral convergence are measured at multiple locations in the ESF North and South Ramps, TS Main Drift, ECRB Cross Drift, alcoves, niches, and auxiliary excavations using rod or tape extensometers. Stress measurements are made at stations located near faults or other areas of interest. *In situ* stress is measured in boreholes drilled from within the north ramp test alcoves using either overcoring or other techniques. Induced stress and stress change tests are conducted in the Thermal Testing Facility (TTF) and behind the TBM using slot tests in the tunnel walls and in radial boreholes using small hydraulic powered chain saws and the Interfels Borehole slotter system. Additional stress testing is ongoing at the point where the ECRB Cross Drift crosses over the TS Main Drift. If a concrete liner is used, stations may also include pressure cells to measure radial and hoop stress changes over time as construction continues beyond the test location. If the access is unlined, load cells on rockbolts will provide an indication of support loading in place of the liner instrumentation. (YMP 1999b)

6.9.2 Monitoring of Ground Support Systems

The objectives of the monitoring of ground support systems activity are to develop recommendations for ground support methods to use in drifts in the potential repository, based on evaluations of the ground-support methods used in the ESF, and on experimentation with other ground-support configurations. This activity is conducted in ESF main openings (such as both ramps, the TS Main Drift, ECRB Cross Drift, and associated auxiliary excavations) and will be conducted in any additional ESF major drifts (such as ECRB Cross Drift and CH Drift) that may be constructed. The selection, installation, and performance of the support systems used are monitored. Experimentation with ground support includes pull tests on rockbolts and installation of rockbolt load cells. In addition, observations are made of unsupported rock; strength measurements are taken on shotcrete cores, and trials of ground-support systems (different from those currently prescribed for the ESF) may be conducted. (YMP 1999b)

6.9.3 Monitoring Drift Stability

The objectives of the monitoring drift stability activity are to: (1) provide confidence in predictions of usability of the potential repository underground facilities over their operational life, (2) contribute to the evaluations of the effectiveness of mining methods and ground supports, (3) calibrate and refine criteria to determine stability of the openings, and (4) develop techniques to monitor stability of the potential repository drifts. These tests monitor drift convergence and drift maintenance activities throughout the ESF, along accesses, at the point where the ECRB Cross Drift crosses over the TS Main Drift, and in the CH if tunnels are mined in this formation. Convergence measurement stations are selected by the PI. Where possible, convergence measurements are taken in a continuous manner. Rock-mass relaxation is investigated using MPBXs. Rock falls and maintenance activities are also documented. (YMP 1999b)

6.9.4 Deformation Monitoring

An activity related to construction monitoring involves the installation of a laser strain-monitoring device along the South Ramp of the TS Loop. The deformation monitoring activity will provide data related to the proposed repository from: (1) long-term tectonic changes, (2) earth tides, (3) free oscillations of the earth, (4) barometric pressure changes, (5) static deformations caused by local earthquakes and explosions, (6) triggered slip along nearby faults caused by transient earthquake waves and explosion strains, and (7) development of the potential repository itself, including its mining and heating. Per YMP (1999c), an approximately 500 m long vacuum tube will be installed along the right rib of the South Ramp in the vicinity of Station 65+00 to 70+00. The tube will be nominally one to three meters above the invert and will be supported by up to three monuments (two at its ends and potentially one in the middle) and various smaller brackets. The monuments are nominally one-meter deep by two-meters high by two-meters long, made using an approved cement and poured in place. Up to four small mined out sections of the right rib, nominally one-meter deep by three meters high by two meters long are required for installation of the monuments, electronics, and vacuum pump(s). The brackets will be installed using small bolts similar to those used for construction utilities in the TS Loop. Four to six boreholes, nominally four to six inches in diameter, (two at each of the two end monuments plus up to two additional instrumentation boreholes) were wet-drilled to a depth of approximately 15.2 m (nominally two tunnel diameters) for the installation of laser optical anchors (laser reflection devices). The boreholes were drilled nominally 30 degrees off-center with a line perpendicular to the rib. The boreholes were drilled nominally horizontal, with a possible slight downward angle to facilitate straighter boreholes. The borehole casing and optical anchor laser reflection devices will be grouted into these boreholes, using approved grouts, additives, and casing materials.

6.9.5 Radiological Monitoring

Monitoring of air quality and ventilation systems was previously included in YMP (1999b), but was eliminated in later revisions. The radon emanation aspects of the Subsurface ESF are now addressed by FWP-ESF-98-001 (YMP 1999d). YMP (1999d) controls radiological monitoring and data collection activities to include radon concentration, radon progeny, radioactive airborne particle, and ambient gamma measurements. Some aspects of ventilation system monitoring are also included in FWP-ESF-96-004 (YMP 2000c).

6.10 MOISTURE STUDIES

Moisture studies in the ESF are conducted to refine understanding of the moisture conditions in the Subsurface ESF, including the ECRB Cross Drift and auxiliary excavations, excavated areas and adjoining rock matrix. The purpose of moisture studies in the ESF is to: (1) document tunnel baseline conditions and effects of various construction and operating activities; (2) conduct hydrologic testing, infiltration, percolation, and seepage flux measurements, and data collection for the unsaturated and saturated stratigraphic zones exposed in the ESF; (3) use the information gathered from these studies to continue the development of process models to support system performance assessment, site recommendation, and license application; (4) determine a mass water balance for material excavated during construction; (5) provide information for hydrologic imbibition with consideration to airborne industrial hygiene issues; and (6) associate information and technical skills used for moisture studies to help correlate and assimilate additional information that could enhance the planned testing activities and the testing data that are required for performance assessment. The results of this testing are used as input to hydrologic modeling calculations for the entire Yucca Mountain area and as inputs to hydrologic models. FWP-ESF-96-004 (YMP 2000c) describes and governs the conduct of the moisture studies activities.

6.10.1 Moisture Study Boreholes, Coreholes, Monitoring Stations, and Drip Trays

Boreholes and/or coreholes are drilled and instrumented to obtain moisture information such as determinations of water potential, temperatures, rock permeability and porosity. The number and locations of the boreholes and/or coreholes are determined to provide the best coverage of the desired Subsurface ESF areas. The holes are drilled from the main tunnel/drift only (i.e., no moisture studies boreholes/coreholes are drilled from any of the testing alcoves) and are generally located below the springline of the tunnel with a slight (one to two degree) up angle to avoid fluid collection. The holes are nominally 2 to 10 m in length with an HQ-sized diameter (similar in size to a rockbolt hole). The PI may also drill short boreholes, nominally 0.5 m in length by 2.5 centimeters (cm) in diameter. The majority of the moisture studies boreholes and coreholes were drilled before the approval of Revision 00 of this DIE. However, there is a possibility of drilling additional holes. The monitoring of the emplaced instrumentation may continue for several years. (YMP 2000c)

Several semi-stationary monitoring stations are used throughout the ESF. These stations monitor air temperature, relative humidity, barometric pressure, and in some cases wind speed in selected locations in the TS Loop and ECRB Cross Drift. In addition, infrared monitoring of the tunnel walls is performed in selected locations. The information collected feeds an overall analysis of water movement in the ESF. (Parsons 1998; Scott 1998)

Drip trays may be installed in areas where significant water influx is possible. Some of these drip collection systems may be attached to the existing ground support system and would be subject to the requirements of CRWMS M&O (1996a). CRWMS (1998e) evaluates one such set of drip trays hung from existing ground support. A series of small (nominally 20 cm by ¼ inch diameter) boreholes are also instrumented at the point where the ECRB Cross Drift crosses over the TS Main Drift (Brake 1998a).

6.10.2 TS Main Drift Drift-Scale Flux and Niche Studies

Niches are evaluated as temporary testing accommodations. The location of these niches is coordinated between the TCO and the M&O's Repository Subsurface Design Organization. If the potential repository layout design is changed (after the excavation of these niches), the location of the niches must be factored into the new design, including potentially evaluating these niches as permanent accommodations. Per Hollins and Mitchell (1997), the niches will be used to: (1) measure the field permeability of proposed repository rock for use in unsaturated zone site-scale models and unsaturated zone drift-scale sub-models, (2) determine the threshold of flow into a drift with finite liquid release to represent an episodic fast flow arrival into the proposed repository horizon, and (3) quantify interaction and monitor fast flow paths and non-paths and non-fast pathway zones into the proposed repository horizon.

Hollins (1997a) and Mitchell (1997a) describe two small testing niches that were excavated during Fiscal Year 1997 in the west (right) rib of the TS Main Drift (which places these niches within the potential repository waste isolation standoff zone). Niche #1 was excavated at approximately Station 35+66 m. Niche #2 was excavated at approximately Station 36+50 m. The niches were excavated at a centerline azimuth of approximately 315 degrees at a 0 percent slope (within standard engineering tolerances). Thus, the centerline of the niches intersect the TS Main Drift at approximately Stations 35+69.4 m and 36+53.4 m, respectively. The niches have a minimum width of four meters and a minimum height of four meters (at the top of an arched crown). The minimum distance between the terminal face of a niche and the right rib of the TS Main Drift is about five meters.

Hollins (1997b); Mitchell (1997b) describe two additional niches were excavated during Fiscal Year 1998. Niche #3 was excavated on the right rib of the TS Main Drift near the location where the ECRB Cross Drift crosses the TS Main Drift at approximate Station 31+03.5. Niche #4 was excavated on the right rib of the TS Main Drift near Station 47+84.8 m. The final locations of Niches #3 and #4 were coordinated with the M&O's Repository Subsurface Design Department to ensure they would not interfere with the repository emplacement drift layout design (Mitchell 1997b). Niches #3 and #4 were excavated mechanically with only minor differences from Niches #1 and #2 (e.g., approximate height of the niches is approximately 3.3 m and a slight positive slope upward from the TS Main Drift was required). Consistent with previous ESF construction operations diesel-powered equipment was used to remove the muck from the excavated areas.

As described in Hollins and Mitchell (1997); Mitchell (1997b), the niches are designed to provide access to a semicircular testing zone with a radius of approximately 15 m. The testing zone consists of the niche excavation and its associated testing boreholes. Up to 10 testing boreholes were drilled for Niches #1 and #2. The boreholes varied in length from approximately 5 to 10 m. Borehole drilling (for both testing and ground support) was performed using dry-drilling techniques only, which included the use of SF_6 as a tracer gas. Three boreholes were drilled approximately one meter above the crown of Niche #1 (parallel to the planned niche excavation), and similarly, one borehole was drilled approximately one meter above the crown of Niche #2. Two boreholes per niche were also drilled within the footprint of the niche (parallel to the planned niche excavation) at the niche springline. Water, traced with LiBr and mixed with aqueous dyes, was then released into these boreholes. Similar activities with potential minor variations in the number and depth of the boreholes (i.e., 7 boreholes--approximately 10 m deep before excavation and 6 boreholes--approximately 10 m deep after construction in each niche) were performed in Niches #3 and #4.

Mitchell (1997c, 1998a) identify the proposed aqueous dyes and microspheres for release in the TS Loop niches testing activities. These dyes (which are generally categorized into two types--common food color dyes and fluorescent dyes) and microspheres are as follows:

- Federal Food, Drug, and Cosmetic Act (FD&C) Blue No. 1 (food color)
- FD&C Red No. 40 (food color)
- FD&C Yellow No. 5 (food color)
- FD&C Yellow No. 6 (food color)
- Amino G Acid
- Fluorescein (water soluble)
- Lissamine (Acid Yellow No. 7)
- Pyranine
- Rhodamine B
- Rhodamine B Sulfo
- Rhodamine WT
- Fluorescent Polystyrene Microspheres (Niches #3 and #4 only)

Mitchell (1997c, 1998a) also provided estimated maximum concentrations for each TFM. However, the PI subsequently reevaluated the Mitchell (1997c) proposed dyes for Niches #1 and #2 and the proposed concentrations, because preliminary feedback from the SA DIE team indicated that the evaluated limit (Section 11 of CRWMS M&O 1999a) for committed organic materials would be exceeded at these concentrations. Due to a lack of other practical, inorganic, alternative dyes, the PI subsequently revised the proposed, maximum concentration of the aqueous dyes to approximately 10 grams per liter, or about 10,000 parts per million (ppm), for all food color dyes and to approximately two grams per liter (about 2,000 ppm) for all fluorescent dyes in Niches #1 and #2 (Mitchell 1997a). These concentrations represent the minimum allowable levels necessary to achieve valid testing results (Mitchell 1997a). For Niches #3 and #4, the maximum concentrations of the aqueous dyes is approximately 10 grams per liter, or about 10,000 ppm, for all food color dyes, approximately 0.9 grams per liter (about 900 ppm) for Rhodamine B, and approximately 4 grams per liter (about 4,000 ppm) for all other fluorescent dyes (Mitchell 1998a). A total of 40 grams of Fluorescent Microspheres was also requested for use in Niches #3 and #4 (Mitchell 1998a). Mitchell (1998a) also identified two organic developers (Sodium Hypochlorite and Potato Starch) that will also be used for visually enhancing other tracer-stains on excavated rock, but will not be committed to the Subsurface ESF.

Per Hollins and Mitchell (1997), less than approximately 100 gallons of the LiBr-traced water/dye(s) mixture(s) was to be released into the testing zone of each niche. However, since the quantity of committed organic material is directly proportional to the total volume of the traced water/dye mixture, the PI also revised the proposed amount of LiBr-traced water/dye mixture to be released into these boreholes. Per Mitchell (1997a), approximately 42 liters (about 11.1 gallons) of the traced water/food color dye mixture were released into the three boreholes above Niche #1, and 84 liters (about 22.2 gallons) of the traced water/fluorescent dye mixture were released into the two boreholes at the springline of Niche #1 (for a total Niche #1 traced water/dye mixture volume of approximately 33.3 gallons). Approximately fourteen liters (about 3.7 gallons) of the traced water/food color dye mixture were to be released into the borehole above Niche #2, and fourteen liters (about 3.7 gallons) of the traced water/fluorescent dye mixture were to be released into the two boreholes at the springline of Niche #2, (for a total Niche #2 traced water/dye mixture volume of approximately 7.4 gallons). These volumes of traced water/dyes mixtures represent the minimum allowable levels necessary to achieve valid testing results, based upon the proposed dye concentrations above (Mitchell 1997a). Similar calculations can be performed for the quantities of traced water/dyes mixtures requested for Niches #3 and #4 (Mitchell 1998a). The results yield approximate volumes of dyed water in Niches #3 and #4 testing activities to be 56 liters (about 14.8 gallons) for food color dyes and 23.1 liters (about 6.1 gallons) for fluorescent dyes.

As discussed in Hollins and Mitchell (1997), some of the dye/traced water mixture released into these boreholes occurred before the niches were fully excavated. Excavation of the given niche began on a schedule as directed by the TCO. Excavation was performed using dry excavation techniques (i.e., using minimal construction water). Grab samples of muck from the niches were collected and sampled for dye infiltration. After excavation of a given niche was completed, the remaining boreholes were drilled on the inside perimeter of the exposed niche surface. The core samples were then analyzed for dye infiltration and other hydrologic characteristics.

The original plan for these tests (as described in Hollins and Mitchell 1997) also required the additional excavation of a small opening (approximately one to 1.5 m in diameter by 5 m deep) around boreholes from which core samples revealed fluid infiltration. (These openings were intended to determine the spatial distributions of the permeability, water content and dye imprints). However, the excavation of these small openings is not bounded by this evaluation. This activity will require additional evaluation, should the TCO determine that these openings are required.

Per Hollins and Mitchell (1997), no special ventilation accommodations were required for these niches, but standard power and lighting accommodations were provided. Mitchell (2000c) describes the addition of humidifiers in some niches to minimize moisture losses from the test bed. Instrumentation to monitor the niches was installed using POLYCEL Expanding Foam and the niches were sealed with bulkheads to allow the enclosed rock mass to equilibrate to ambient conditions. VERSI-FOAM has also been requested for use in sealing sections of boreholes for further niche testing. Shotcrete was placed around the perimeter of the bulkhead frames to seal them (Mitchell 1997d).

Per Mitchell (1997c, 1998a), single-hole and cross-hole gaseous tracer testing will be performed in the niches. SF_6 is the only gaseous tracer requested for Niches #1 and #2 testing. SF_6, SUVA COLD MP® (tetra fluoroethane), and noble gases (i.e., Helium, Neon, Argon, Krypton, and Xenon) are the gaseous tracers requested for Niches #3 and #4 testing. The gas tracer testing is essentially similar to the radial borehole testing described above, but on a smaller scale.

Mitchell (1998b) requested the use of new tracers in Niche #2 to quantify the extent of the wetting front from traced water introduced in the boreholes above niches. The test zones were picked to maximize the spreading of the traced water. One to two meter long boreholes will be drilled into the crown and sidewalls of the niche after the traced water is applied to provide core samples for subsequent analysis to determine the extent of the wetting area. Tracer concentrations will be monitored as part of the test. The tracers proposed for use include:

- 2,3-Diflurobenzoic Acid
- Pentafluorobenzoic Acid
- Calcium Bromide
- Calcium Iodide
- Sodium Iodide

The tracers will be released in an existing borehole located in the upper middle quadrant approximately 0.75 m above Niche #2. The traced water releases occurred in nominally one-foot intervals of the borehole isolated by packers. The total volume of water released during the tests was not to exceed 20 liters. (Mitchell 1998b)

Based on the results of this additional tracer release in Niche #2, the tracers listed in Mitchell (1998a) that were not listed above are still requested for use in Niches #3 and #4. These tracers include:

- 2,3-Diflurobenzoic Acid
- 2,4-Difluorobenzoic Acid
- 2,5-Difluorobenzoic Acid
- 2,6-Difluorobenzoic Acid
- 3,4-Difluorobenzoic Acid
- 3,5-Difluorobenzoic Acid
- 2,3,4-Trifluorobenzoic Acid
- 2,3,6-Trifluorobenzoic Acid
- 2,4,5-Trifluorobenzoic Acid
- 2,4,6-Trifluorobenzoic Acid
- 3,4,5-Trifluorobenzoic Acid
- 2,3,4,5-Tetrafluorobenzoic Acid
- 2,3,4,6-Tetrafluorobenzoic Acid
- Pentafluorobenzoic Acid
- Magnesium Fluoride
- Potassium Fluoride
- Sodium Fluoride
- Sodium Chloride
- Lithium Bromide
- Potassium Bromide
- Sodium Bromide
- Magnesium Iodide
- Potassium Iodide
- Sodium Iodide

The maximum volumes and concentrations of these tracers in Niche #3 and #4 are 350 liters (about 92.5 gallons) at a concentration of approximately 0.02 grams per liter (20 ppm) for Fluoride organics (i.e., Di, Tri, Tetra, and Pentafluorobenzoic Acids), 30 liters (about 7.9

gallons) at a concentration of approximately 5 grams per liter (5,000 ppm) for Fluoride salt compounds, 45 liters (about 11.9 gallons) at a concentration of approximately 5 grams per liter (5,000 ppm) for non-fluorinated salts (bromides, iodides, and sodium dihydrates excluding sodium chloride and LiBr), 20 liters (about 5.3 gallons) at a concentration of approximately 3 grams per liter (3,000 ppm) for sodium chloride, and 20 liters (about 5.3 gallons) at a concentration of approximately 2 grams per liter (2,000 ppm) for LiBr in excess of the 20 ± 10 ppm allowed for tracing construction water.

6.10.3 Alcove Slot Cut Testing

Mitchell (1998c, 1998d); YMP (2000c) provide a description of the alcove slot cut construction activities in ESF Alcoves #4 and #6. Mitchell (1998c) provides a generic description of the alcove slot cuts and the boreholes used to inject tracer material above the slot cuts. The two slot cuts are nominally less than five meters wide by less than five meters deep with a height of less than one-half meter. The Alcove #4 slot cut is located at the terminal (north) end of the alcove with a potential expansion of the slot cut into the last approximately one meter of the left (west) rib of the alcove. The Alcove #6 slot cut is located along the right (south) rib of the alcove beginning at approximately alcove Station 0+55 m.

Per Mitchell (1998c), the alcove slot cuts were excavated using wet or dry-drilling techniques as follows. A line of NQ-3 size pilot holes are drilled at about one-foot intervals along the planned centerline of the slot cut. A one foot diameter tri-cone reaming bit was used to drill overlapping holes using the pilot holes as guides for the reaming bit. This resulted in a roughly rectangular shaped slot (with small irregularities across the top/bottom of the slot caused by the use of a round reaming bit to create a rectangular cut). Small support jacks were inserted into the slot cut to provide support to the surrounding rock and keep the slot cut from collapsing. Boreholes were dry-drilled in a pattern determined by the PI(s) above the given slot cut in preparation for tracer testing. The boreholes extend beyond the depth of the slot cuts, but were packed off such that the releases of tracers only occur above the slot cut. Mitchell (1998e, 1998f) provided a list of the proposed TFMs, associated quantities/concentrations, and description of the methods for their injection into the boreholes above the respective alcove slot cuts. These included the following major types of TFMs:

- Fluorescent Dyes (Organics) (same as those listed for niches above)
- Food Color Dyes (Organics) (same as those listed for niches above)
- Fluorescent Microspheres (Organics) (same as listed for niches above)
- Fluorinated Organics (Di, Tri, Tetra, and Penta fluoride-substituted benzoic acids--same as listed for niches above)
- Fluorine Salts (same as listed for niches above)
- Non-Fluorine Halogenated Salts (same as listed for niches above)
- Non-Halogenated Salts (same as listed for niches above)
- Organic Developers (not to be committed to the ESF)
- Gases (same as listed for niches above)

Gas tracer testing was performed between the boreholes drilled above the alcove slot cuts. The gas tracers are listed in Mitchell (1998a, 1998e, 1998f). The gas tracer testing is essentially similar to the radial borehole testing described above, but on a smaller scale. For the liquid tracer testing, catchments and liners were used in the slot cut to collect and segregate any traced water that falls into the given slot cut.

6.10.4 Alcove Infiltration Testing

Brake (1997) describes the activities associated with the infiltration testing into Alcoves #1 and #7. Bulkheads discussed below have been installed in Alcoves #1 and #7 to seal sections of each alcove from the TS Loop. These sealed sections provide a monitoring environment conducive to water seepage into the alcove from fracture flow. The testing in Alcove #1 uses traced water applied to the surface above the alcove. The Alcove #7 testing uses only the naturally occurring water (i.e., surface precipitation). An additional infiltration test is planned between Alcove #8 in the ECRB Cross Drift and Niche #3 in the TS Loop and is discussed in Section 6.10.5 below.

For Alcove #1, instrumentation is installed in the alcove to monitor: (1) the relative humidity and temperature of the air; (2) evaporation processes on the alcove walls; (3) changes in water potential; and (4) water content in the walls and boreholes, as well as drips of water from fractures, faults, and/or rock bolts. In addition, instrumentation was placed in the rock behind applied shotcrete to simulate the effects of pre-cast or cast-in-place liners on the water movement. The instrumentation was installed in existing boreholes (including boreholes previously used for radial borehole tests) and in short (nominally less than two meter HQ-size) boreholes hand-drilled into the crown and rib(s) of the alcove. The instrumentation for Alcove #1 includes heat dissipation probes, psychrometers, temperature and relative humidity probes, pressure transducers for measuring barometric pressure, drip collection systems, and packer strings for boreholes. Neutron logging of boreholes is also performed.

Per Brake (1997), traced water (using LiBr as the tracer) was applied during the initial testing phase to the ground surface directly above Alcove #1 by intermittent application from a Polyvinyl Chloride (PVC) pipe drip irrigation system. Intermittent traced water was applied at a rate of 2 cm (0.8 inches) per day for 100 days or 1 cm (0.4 inches) per day for 200 days. The water was applied roughly equally to a 35 foot by 26 foot area (Guertal 1998). This equates to approximately 450 gallons per day for the first application rate and 225 gallons per day for the second application rate.

Mitchell (1998g) describes the use of additional tracers and traced water. This next phase of testing includes the addition of approximately 60,000 gallons of traced water. The application rate is expected to average 4 cm (1.6 inches) per day and should not exceed a maximum rate of 8 cm (3.2 inches) per day. The following tracers are used during the infiltration testing into Alcove #1:

- Lithium Bromide
- FD&C Blue No. 1 (food color)
- Fluorescein (water soluble)
- Pyranine
- Rhodamine WT
- Sodium Chloride

- Calcium Bromide
- Calcium Iodide
- Sodium Iodide
- Magnesium Fluoride

Two requests for additional water have been received. The two requests (Mitchell 1999a, 2000b) were for 60,000 gallons of traced water each. Thus, the total quantity of water requested for release above Alcove #1 is 245,000 gallons. The quantity of tracer originally requested for release with the water above Alcove #1 is still considered sufficient to complete the planned testing.

The traced water application area is covered with plastic sheeting elevated approximately one foot above the ground surface. This sheeting helps warm the area and isolates the test and its measured rate of water application from uncontrolled external influences (e.g., wind, rain). Brake (1997) also notes that the water application area is approximately 30 m (100 feet) above the Alcove #1 test area.

Alcove #1 is located at approximately Station 0+42.6 m into the ESF Starter Tunnel. CRWMS M&O (1997b) indicates that the bulkhead installed in Alcove #1 is at approximately alcove Construction Station 0+83 feet (25.3 m), which isolates the final approximately 9 m of the alcove from the ESF Starter Tunnel.

Brake (1997) and CRWMS M&O (1997b) also discuss the Alcove #7 portion of the infiltration testing. The instrumentation used in Alcove #7 includes heat dissipation probes, psychrometers, temperature and relative humidity probes, and pressure transducers for measuring barometric. In addition, a rain storage gage and heat dissipation probes were installed on the surface above Alcove #7. The above ground instrumentation is used to monitor the naturally occurring water at the ground surface above Alcove #7. No additional traced water is planned to be applied above Alcove #7.

6.10.5 ECRB Cross Drift Niches, Alcoves, and Slot Cuts

Per Scott (1998), a number of niches and alcoves were planned to be excavated off the ECRB Cross Drift. Some of these excavations include additional slot cut testing and associated boreholes between the niche/alcove and the ECRB Cross Drift. YMP (2000c) describes two of these activities that will be occurring in the near future. Specifically, a cross over alcove (Alcove #8) positioned above TS Loop Niche #3 will be excavated off the left rib of the ECRB Cross Drift (approximate ECRB Station 7+98 m) and a niche will be excavated off the left rib of the ECRB Cross Drift at approximate ECRB Station 16+20 m (Niche #5). Per Schulenburg (2000) Alcove #8 may be used as a refuge station in the event of an emergency. The refuge station will use the Alcove #8 bulkhead and including placement of necessary emergency equipment. An additional niche has been proposed at approximate ECRB Station 23+46 m (Niche #6), however, this niche is not currently funded. CRWMS M&O (2000a) provides a detailed discussion of the dimensions, orientations, and methods of construction activities required for these excavations. Descriptions of the planned testing activities and information related to the actual testing area are provided below. The excavation and construction of the ECRB niches, alcoves, and slot cuts has been allocated to CRWMS M&O (2000a).

Niche #5 is similar in design and function to the TS Loop niches with the exception that an access drift is used to separate it from main drift of the ECRB Cross Drift. Up to 18 boreholes will be installed at Niche #5 to provide access to the rock mass for monitoring and testing purposes and for the collection of rock core samples for subsequent off-site testing and evaluation. Three out of the approximately 18 boreholes were installed prior to excavating the access drift leading to the niche. Air injection tests are performed in these boreholes prior to mining out the access drift and after the niche is excavated to evaluate the effects that excavation has on rock air permeability distributions. Up to nine boreholes will be installed parallel to the niche axis, with subsequent air injection and liquid release testing being conducted prior to and after niche construction. The end of the holes that are located outside the limits of the proposed footprint of the niche will also be tested after niche construction. Following niche construction, up to six radial boreholes will be drilled within the niche, with subsequent testing and monitoring being conducted within these holes to monitor ambient hydrologic conditions within the rock mass. (Mitchell 1999b)

A temporary testing bulkhead, similar to those used in previous niche testing will be installed using shotcrete or a similar approved sealing material for isolation of the test area. Mitchell (2000c) describes the addition of humidifiers in some niches to minimize moisture losses from the test bed. Niche #5 is located such that a second stratigraphic layer of rock will be tested. Niche #6 will be positioned in a third stratigraphic layer of rock, and if funded, is anticipated to be of similar design and function as Niche #5. Tracer concentrations will be monitored with approved and calibrated systems including, gas chromatograph mass spectrometer, fluorescence spectrophotometer, ion specific electrode ion chromatography, gas chromatography-electron capture detector, gas chromatography-thermal conductivity detector, and UV-vis spectrophotometer. The following TFMs have been proposed for use in the region of rock located in the vicinity of (primarily above) Niche #5:

- Approximately 54 liters (about 14.3 gallons) of the traced water/food color dye mixture, 4.4 liters (about 1.2 gallons) of the traced water/Rhodamine B mixture, and 27 liters (about 7.1 gallons) of the traced water/fluorescent dye mixture was requested for release into the Niche #5 boreholes (for a total Niche #5 traced water/aqueous dye mixture volume of approximately 22.6 gallons). The maximum concentrations of the aqueous dyes is approximately 10 grams per liter, or about 10,000 ppm, for all food color dyes, 0.9 grams per liter, or about 900 ppm, for Rhodamine B, and 4 grams per liter, or about 4,000 ppm, for all other fluorescent dyes.

- Approximately 350 liters (about 92.5 gallons) of the traced water/organic Fluoride compounds and 30 liters (about 7.9 gallons) of the water/Fluoride salt compounds were requested for release the Niche #5 boreholes (for a total Niche #5 water/Fluoride compound mixture volumes of approximately 100.4 gallons). The maximum concentrations of the water/Fluoride compounds is approximately 0.02 grams per liter, or about 20 ppm, for organic Fluorides and 5 grams per liter, or about 5,000 ppm, for Fluoride salts.

- Approximately 105 liters (about 27.7 gallons) of the traced water/non-fluorinated salts (bromides, iodides, and sodium dihydrates excluding sodium chloride and LiBr), 20 liters (about 5.3 gallons) of traced water/sodium chloride, and 20 liters (about 5.3 gallons) of traced water/LiBr (above 20 ± 10 ppm) was requested for release into the Niche #5 boreholes (for a total Niche #5 traced water/non-fluorinated salt mixture volume of approximately 38.3 gallons). The maximum concentrations of the non-fluorinated salts is approximately 5 grams per liter, or about 5,000 ppm, for non-fluorinated salt (excluding sodium chloride and LiBr), 3 grams per liter, or about 3,000 ppm, for sodium chloride, and 2 grams per liter, or about 2,000 ppm, for LiBr.

- Approximately 5,000 liters of the noble gases, 20 liters of Nitrogen, 20 liters of SUVA COLD MP® (tetra fluoroethane), and 1000 liters of SF_6 were requested for release into the Niche #5 boreholes. The maximum concentrations of these gases are approximately 1 grams per liter, or about 1,000 ppm for the noble gases, 0.02 grams per liter, or about 20 ppm, for Nitrogen, 0.02 grams per liter, or about 20 ppm, for SUVA COLD MP® (tetra fluoroethane), and 1 grams per liter, or about 1,000 ppm, for SF_6.

- A total of 80 grams of Microspheres were also requested for release into the Niche #5 boreholes. Approximately 100 liters (about 26.4 gallons) of traced water is expected to be used in releasing the Microspheres into the Niche #5 boreholes.

- Two organic developers (Sodium Hypochlorite and Potato Starch) were also requested for use for visually enhancing other tracer-stains on excavated rock, but are not expected to be committed to the Subsurface ESF. (Mitchell 1999b)

Alcove #8 was constructed from the left rib of the ECRB Cross Drift in a manner such that it will overlie TS Loop Niche #3. The alcove is approximately one meter wider than Niche #3 with roughly one-half meter extension beyond each rib of Niche #3. The alcove's length is such that it will overlie a small portion of the TS Main Drift just outside of Niche #3 (approximately one meter beyond the right rib of the TS Main Drift). This extension beyond the Niche #3 test area will facilitate a preliminary test to be conducted in the back of Alcove #8 to ensure that an adequate recovery of water is demonstrated (Mitchell 2000a). The preliminary test will consist of two phases. The first phase will use a small disk infiltrometer to introduce a small quantity of traced water to characterize the rock and fracture system. The second phase will be a small scale test, approximately one meter by one meter, similar to the main test planned in Alcove #8. Mitchell (2000d) describes a proposed expansion of the small scale test to include a trench (nominally 15 cm deep by 40 cm wide) along a fault near the one meter by one meter test area. The trench would be separated into smaller segments using small dividers made out of grout. A removable steel or plastic plate would be used to cover the trench to avoid tripping hazards and minimize adverse evaporation. This expansion of the small scale test is expected to speed the water recovery process and increase the probability of locating any fast pathways between Alcove #8 and Niche #3. Traced water will be introduced into the small scale test bed and recovered below in the TS Main Drift, directly in front of Niche #3, and/or within Niche #3. An air block will be installed just ahead of the expected recovery location in the TS Main Drift to minimize the impacts of ventilation on the recovery effort. An additional small scale test has been performed on the bulkhead side of the main Alcove #8 test area. Preliminary results of this testing are provided in Section 11.1.5. The main test in Alcove #8 combines passive and active testing program to monitor and measure induced seepage into Niche #3 and includes an approximate three meters by four meter water introduction area filled with a substance such as "Overton" type sand to distribute the water evenly. A painted metal frame approximately 30 cm high will divide the test bed into 1 m square sections and will be grouted into place on the invert of Alcove #8. A small kerf, approximately 1 to 2 inches wide by 0.5 inches deep, may be excavated in the invert to install the metal frame. Additional leveling of the alcove invert may be required to optimize the test bed. Up to 10 concrete slabs, approximately 1 m by 1 m, will be installed in Alcove #8 to support the precise load cells required to monitor the weight loss of the liquid tracers. (Mitchell 2000a)

Neutron logs, heat dissipation probes, time domain reflectometry, tensiometers, and other instrumentation will be used to monitor the induced seepage from Alcove #8 into Niche #3. In addition, ground penetrating radar is planned to be used to monitor the wetting front between Alcove #8 and Niche #3. In order to use these penetrating radar techniques, one nominally three-inch diameter borehole will be drilled between Alcove #8 and the Niche #3 area (Mitchell 2000a). This borehole facilitates the time sensitive signal transfer between the two locations during the penetrating radar tests. The borehole will be elevated approximately 0.75 m above the invert in Alcove #8 so as to minimize the potential for liquid transfers directly between the two excavations.

The installation of "cut-outs" on the three perimeter sides of Niche #3 has been proposed to enhance the ability to monitor and collect water passing around the excavated opening of the niche. The "cut-outs" would consist of slots cut into the two ribs and terminal end of Niche #3, approximately 0.75 m above the invert. The "cut-outs" would be angled slightly upward and be approximately 1 to 1.5 m deep. Similar "cut-outs" have been proposed for Niche #5, but they would be excavated approximately 2.5 m above the invert. (Mitchell 2000a)

As much as 100,000 gallons of traced water has been proposed for introduction into Alcove #8 with a collection system in Niche #3. Rates of water application are planned to be between 10 to 100 gallons/hour using a calibrated flow meter. In addition, a temporary testing bulkhead has been installed to isolate the water distribution system in Alcove #8. This bulkhead is similar to other niche/alcove bulkheads and has been sealed using shotcrete or a similar approved material. The following tracers (with quantities and concentrations) have been proposed for application into the Alcove #8 water distribution system: (Mitchell 1999c)

- Lithium Bromide (140 Kilograms [kg] at 600 ppm)
- Fluorescein (water soluble) (0.2 kg at 1 ppm)
- Pyranine (0.2 kg at 1 ppm)
- Rhodamine WT (0.2 kg at 1 ppm)
- Sodium Chloride (550 kg at 2,000 ppm)
- Calcium Bromide (140 kg at 500 ppm)
- Calcium Iodide (2 kg at 10 ppm)
- Sodium Iodide (2 kg at 10 ppm)
- Magnesium Fluoride (20 kg at 87 ppm)

Additional water and proposed tracers have been requested for the Alcove #8/Niche #3 testing (Parsons 2001a, 2001b) . Up to 150,000 gallons of water (Mitchell 2001) has been proposed to inject with the following tracers into Alcove #8 test-beds:

Tracer	Total quantity	concentration
Lithium Bromide	1,000 gram	500 ppm
Calcium Chloride	2,000 gram	2,000 ppm
Potassium Fluoride	100 gram	50 ppm
Potassium Iodide	50 gram	10 ppm
2,3-Difluorobenzoic Acid	50 gram	50 ppm
2,4-Difluorobenzioc Acid	50 gram	50 ppm
2,5-Difluorobenzoic Acid	50 gram	50 ppm
2,6-Difluorobenzoic Acid	50 gram	50 ppm
3,4-Difluorobenzioc Acid	50 gram	50 ppm
3,5-Difluorobenzoic Acid	50 gram	50 ppm
2,3,4-Trifluorobenzoic Acid	50 gram	50 ppm
2,3,6-Trifluorobenzoic Acid	50 gram	50 ppm
2,4,5-Trifluorobenzoic Acid	50 gram	50 ppm
2,4,6-Trifluorobenzic Acid	50 gram	50 ppm
3,4,5-Trifluorobenzic Acid	50 gram	50 ppm
2,3,4,5-Tetrafluorobenzoic Acid	50 gram	50 ppm
Pentafluorobenzoic Acid	50 gram	50 ppm
FD&C Blue No. 1	20 gram	20 ppm
Sulpho Rhodamine B	10 gram	10 ppm
Fluorescein	10 gram	10 ppm
Pyranine	10 gram	10 ppm
Rhodamine WT	10 gram	10 ppm
Lactic Acid Sodium Salt	30 gram	100 ppm
Fluorescent Microspheres	1 Liter	

Additional testing may include a second niche (as discussed above), alcove(s)/drilling for evaluation of the Solitario Canyon fault, and a small-scale thermal test above the repository. The second niche would be used for fracture mechanics studies similar to the TS Loop niches and ECRB Niche #5. A crest alcove (Alcove 9) (positioned in one of the higher anticipated natural infiltration areas of the proposed repository) with bulkheads and monitoring instrumentation similar to that used in alcove infiltration testing was proposed, but the installation of the two bulkheads within the ECRB Cross Drift will likely supplant this testing activity. Slot cut testing may be included that is similar to TS Loop alcove slot cut testing, but on a larger scale. The extension of planned and/or existing boreholes, up to 30 m in length, for the installation of temperature monitoring equipment was also discussed. The testing activities associated with these excavations will be evaluated in a future revision to this DIE or another DIE. (Scott 1998)

Alcove 10 may conduct testing using cross-drift thermal studies. The purpose of these field thermal tests is to better understand the heat-driven coupled processes in the nearfield rock in the potential repository. (YMP 2001)

6.10.6 Chlorine-36 Monitoring and Testing

Chlorine-36 testing is conducted to obtain information about rates and potential pathways for water movement in the UZ at Yucca Mountain. Chlorine-36 testing primarily consists of core and rock sample analysis.. Samples are collected at various locations to include likely transmissive features such as faults, fractures, and breccia zones (Levy et al. 1997). Samples are primarily taken from boreholes drilled for other functions (e.g., radial boreholes, moisture study holes). The samples are processed in the laboratory to determine Chlorine-36 levels. This testing activity is one used to estimate aqueous pathways and travel times from the ground surface to the Subsurface ESF. Additional short boreholes (nominally less than two meters long) and hand-chipped sample blocks (nominally one cubic foot) are excavated at selected locations, as designated by the TCO, for further studies of potential fast pathways in the ESF. No TFMs are emplaced in the Subsurface ESF during Chlorine-36 testing.

As part of the validation efforts associated with earlier Chlorine-36 testing, short, HQ boreholes (nominally 3 to 4 m long) may be dry-drilled near locations in the Subsurface ESF where elevated levels of Chlorine-36 have been detected. Peterman (1998) describes one such validation effort near the Drill Hole Wash and Sundance Fault structures. Mitchell (1999d) describes approximately 10 and 40 boreholes, respectively, drilled off the TS Loop near the areas where it contacts these geologic structures. A few of these boreholes may be up to 10 m deep to facilitate monitoring for potential interactions between the Chlorine-36 boreholes and testing/construction activities. The boreholes are drilled nominally horizontal (±12 degrees of horizontal) at a height of approximately 1.5 m above the invert. All the boreholes are planned to be drilled off the right rib of the TS Loop. The cores from these boreholes are packaged for off-site processing.

6.11 TESTING IN THE TS MAIN DRIFT THERMAL TESTING FACILITY

The TTF is located off the left rib of the TS Main Drift at approximately Station 28+27 m. The TTF is an alcove (Alcove #5) designated for a series of tests as describe below. FWP-ESF-96-003 (YMP 1997d) provides a description of the activities associated with "Thermal Testing in the ESF - Phase I." The TTF was excavated using a combination of drill-and-blast and mechanical mining using a Road Header (Alpine Miner). CRWMS M&O (1999a) evaluated the construction activities associated the TTF.

6.11.1 Thermomechanical Alcove

The TMA (previously identified as the Shakedown Test Area) is a section of the TTF located off the right rib of the Access/Observation Drift (AOD) at approximately alcove Station 0+38.5 m. The TMA and TMA Extension were used to conduct an instrumentation shakedown using a small scale single heater test. Per YMP (1997d), the single heater test objectives were to: (1) provide measurements to examine rock-mass thermal properties; (2) measure changes in rock saturation before, during, and after heating; (3) measure the thermal expansion of the rock mass; (4) investigate the propagation of a drying front and subsequent re-wetting; (5) measure residual saturation levels in the dry zone; (6) examine the validity of conductive thermal models; (7) observe occurrences of liquid reflux in fractures; (8) measure changes in rock-mass and fracture permeability; (9) determine changes in the chemistry of reflux water; (10) measure rock-mass modulus under thermal conditions; (11) evaluate rock-mass strength; (12) observe ground support interactions; and (13) expand an *in situ* test and instrumentation experience base. The TMA/single heater test stage of the Phase I thermal testing is comprised of the following activities:

- Geologic reconnaissance of the structure features in the walls and ceiling of the tunnels. The geologic reconnaissance included the evaluation of fractures, altered zones, and seeps, if observed. Rock quality mapping was carried out to assess the stability of the test bed and to assist in the selection of the location for heater placement.

- The drilling of numerous testing-related boreholes into the pillar between the AOD and the TMA Extension. These boreholes originate from the TMA, AOD, and TMA Extension. While dry drilling of these boreholes was preferred (CRWMS M&O 1996b), drilling with water was allowed due to the realization of significant cost savings. Core samples were collected for laboratory evaluation.

- The performance of pre-test characterization activities in these boreholes, including borehole logging for pressure, temperature, and moisture content; borehole scanning to obtain a visual description of the rock matrix and fractures; and air injection and interference pumping tests to determine permeability.

- The installation of an approximately five-meter long heater assembly and associated instrumentation into the borehole designated for this purpose.

- The installation of a diverse array of instrumentation into designated boreholes, including instrumentation to measure temperature, relative humidity, gas/air pressure, liquid water saturation levels, geochemistry, and mechanical properties. High-temperature grouting material was used in some of these installations; others used high-temperature packers. Geochemical measurement boreholes were equipped with "SEAMIST" (Science Engineering Associates Membrane *In situ* Sampling Technique) or similar assemblies. Boreholes designated for neutron logging (i.e., one of the methods to be used to measure water saturation levels) were fitted with a Teflon tube liner.

- The installation of four instrumented rockbolts into designated holes near the heater assembly.

- The installation of a DCS for data acquisition and recording purposes.

- The conduct of an M&O management-directed preparedness assessment before heater energization.

- The energization of the heater assembly for approximately nine months. The heater was designed such that rock-mass temperatures at minimum radial distance of one meter from the heater exceeded 100 degrees Celsius, with rock-mass temperatures in excess of 200 degrees Celsius adjacent to the heater.

- A cool-down monitoring period of approximately seven months.

- Post characterization activities to include removal of insulation and selected instruments, video logging, air injection testing, Goodman jack testing, pull testing and possible overcoring of rockbolts, dry-coring of new boreholes, and overcoring of various existing boreholes for scientific purposes. (Weaver 1997)

6.11.2 Sequential Drift Mining Studies

Before construction of the Heated Drift, instrumentation was emplaced in the rock mass adjacent to the location of the Heated Drift. These boreholes emanated from the AOD and allowed for excavation investigations referred to as sequential drift mining studies. Per YMP (1997d), the test objectives were to provide measurements to: (1) examine the extent and behavior of the stress-altered region around a newly excavated opening before, during, and after heating; (2) observe and evaluate rock-mass/ground support interactions; (3) provide baseline information for the evaluation of mechanical aspects of Thermal/Mechanical/ Hydrological/Chemical (TMHC) coupling; and (4) evaluate thermomechanical models used to predict rock-mass behavior.

6.11.3 Plate-Loading Testing

The plate-loading test activity is located in the TTF just outside the Heated Drift. Per YMP (1997d), the objectives of the plate-loading testing are to: (1) measure the thermal expansion of the rock mass, (2) measure the rock-mass modulus at elevated temperatures, (3) provide baseline information for the evaluation of mechanical aspects of TMHC coupling, and (4) evaluate thermomechanical models used to predict rock-mass behavior.

6.11.4 Heated Drift Testing

The ESF TTF Heated Drift is located at the end of the TTF parallel to, but offset laterally by approximately 32 m from the AOD. The ESF TTF Heated Drift is the site of the Drift Scale Test (DST). Per YMP (1997d), the DST objectives are to provide measurements to: (1) examine the coupled TMHC processes that may impact potential waste packages; (2) produce *in situ* data on the effect of heat on spatial and temporal distributions of temperature, moisture content, water chemistry, and displacement of rock mass; (3) compare the measured data with model predictions so that coupled process models can be tested; (4) provide a conceptual model and hypothesis test bed for heat transfer mechanisms, heat pipes, buoyant phase, convection condensate refluxing, and binary diffusion; (5) measure corrosion rates on typical waste package materials under *in situ* conditions; (6) evaluate the effect of introduced materials on the near-field environments; (7) evaluate the effect of ground support interactions with the heated rock mass, including the effect of materials used for ground support on the near-field water chemistry; and

(8) provide detailed measurements of the response of the rock mass to the construction and heating of an emplacement size drift.

The closest potential waste package emplacement area to the Heated Drift is the Primary Waste Emplacement (WE) Area, which is located just west of the ESF TS Main Drift (CRWMS M&O 1994a, 1997c). The offset distance between the western rib of the ESF TS Main Drift and the Heated Drift is approximately 77 m (CRWMS M&O 1997c). As noted in CRWMS M&O (1995a), the nearest potential waste package emplacement to the west of the ESF TS Main Drift must be offset by a minimum distance of 37 m, so the minimum offset distance between a potential emplaced waste package and the Heated Drift is approximately 114 m.

Brake (1996) provides an overview of DST activities. YMP (1997d) includes a table (termed the *Administrative Borehole Layout Table*) that identifies the test boreholes drilled in the proximity of the TTF Heated Drift. These boreholes are designated "Drift-Scale Test" in the fourth column of the table. YMP (1997d) also provides a plan view of these boreholes. Approximately 100 boreholes emanate from the TTF Heated Drift itself, with approximately half of these used to situate wing heaters. The other boreholes emanating from the Heated Drift house instrumentation for monitoring temperature, thermal conductivity and diffusivity, rock mass displacement (using MPBXs), and rock water content (using electrical resistivity tomography [ERT]). Other boreholes, outfitted with similar instrumentation, emanate from the Connecting Drift and the AOD. The Administrative Borehole Layout Table (YMP 1997d) indicates that all but three of the boreholes were drilled with traced construction water as the drilling fluid. The three exceptions are "Ambient Characterization" boreholes (borehole numbers 182, 183, and 184) that are designated "dry cored" in the table.

Brake (1996) also identifies various TFMs planned to be used for the Heated Drift testing. This DIE evaluates these TFMs based on their similarity to TFMs that have been previously evaluated in CRWMS M&O (1999a).

Other DST temporary testing accommodations and activities are described as follows:

- The installation of a cast-in-place concrete liner between Stations 00+48.4 and 00+60.75 m (i.e., approximately 12.5 m) of the Heated Drift (CRWMS M&O 1997d, 1997e). The liner is a temporary test component of the DST and was not designed to provide ground support for the Heated Drift. Rather, the liner is being tested to establish the qualitative performance of concrete in a simulated repository environment (CRWMS M&O 1997f).

- The minimum outer diameter of the liner (i.e., the diameter of the excavated opening) is approximately 5.6 m. The inner diameter of the liner (i.e., the exposed surface inside the Heated Drift) is nominally 5.2 m. The minimum wall thickness of the liner is 0.2 m (CRWMS M&O 1997d, 1997e).

- The installation of a cast-in-place concrete invert floor for the entire circular portion of the Heated Drift (approximately 47.5 m in length) (CRWMS M&O 1997c; Weaver 1996a). The invert floor is approximately 1.2 m high (as measured along the center line from the tunnel floor to the top of the concrete invert) (Weaver 1996a). The invert floor serves only as a test support accommodation (i.e., a level floor surface for the Heated Drift). However, the invert floor directly interfaces with a Heated Drift testing component, in that the invert floor is also placed within the cast-in-place concrete liner section of the Heated Drift (Weaver 1996a). Due to this testing interface, the cast-in-place concrete invert floor is being evaluated herein, in lieu of being evaluated in CRWMS M&O (1999a).

In addition to the Heated Drift concrete invert floor, there are five other temporary, cast-in-place concrete applications (i.e., associated with flooring requirements) for the DST. Per Weaver (1996a), four of these applications include a ramp from the elevation of the Connecting Drift floor to the Heated Drift invert floor elevation, a thin floor for the DST Drilling Bay, a thin floor for the short equipment niches, and a load retaining frame (consisting of approximately 11 cubic yards of concrete) for the Plate Loading Niche (which is located on the right rib of the Heated Drift outside the bulkhead near the Connecting Drift). A cast-in-place concrete floor is needed for the entire AOD. Per Morrison (1998), approximately 203 cubic yards of light-weight insulating concrete are needed between the Connecting Drift and the TMA. Approximately 20 to 30 cubic yards of regular concrete are needed between the TMA and the TS Main Drift (Morrison 1998).

- The conduct of pre-test characterization activities in DST boreholes, which includes borehole: (1) logging for pressure, temperature, and moisture content; (2) borehole scanning to obtain a visual description of the rock matrix and fractures; and (3) air injection and interference pumping tests to determine permeability (CRWMS M&O 1996b).

- The installation of heater assemblies. Wing heaters are emplaced in horizontal boreholes along the full length of the Heated Drift at approximately 0.25 m below the springline (CRWMS M&O 1996b). Heaters mounted in canisters are emplaced on the concrete invert floor (CRWMS M&O 1996b).

- The installation of a DCS for data acquisition and recording purposes (CRWMS M&O 1996b).

- The installation of a bulkhead which physically separates the Heated Drift from the rest of the TTF during the conduct of the DST (CRWMS M&O 1996b). The bulkhead does not provide an air-tight seal, rather it is equipped with several penetrations to facilitate instrumentation and power cable passage. The bulkhead is also equipped with cable supports (on the Heated Drift side of the bulkhead) to control cable bend radii, temperature measuring devices, lighting for the Heated Drift side of the bulkhead, two viewing ports for visual inspection of the Heated Drift, and a controlled-access door for testing-support by personnel and a small hand-held equipment access (Hollins 1996).

- The erection of cable trays in the Connecting Drift and Heated Drift; a pre-fabricated building (with air conditioning, power, and lighting accommodations) at the end of the AOD and a test frame in the Plate Loading Niche (YMP 1997d).

- The installation of a designed fire suppression system in the office at the end of the AOD that uses FM-200® "clean agent" as a fire suppression agent (Logan 1997).

- The installation of heater power monitor boxes on the ribs of the Connecting Drift; connection of heater wires to the power monitor boxes; transportation and positioning heater canisters on the invert of the Heated Drift; grouting of instrumentation in boreholes; and sealing of boreholes by applying grout or other mechanisms to the borehole circumferences (YMP 1997d).

- The installation of fiberglass insulation along the exposed surfaces of the AOD, Connecting Drift, and Heated Drift where required to provide protection from the heated rock. An aluminum sheet lagging will be used over the insulation for protection of personnel and the insulation itself. (CRWMS M&O 1998a).

- The initiation of the test by energizing all floor and wing heater assemblies for up to four years. The heater assemblies increase the temperature of the Heated Drift rock walls to approximately 200 degrees Celsius at the end of a two year heating period. If the heating period extends to 4 years, the peak rock wall temperature expected in the Heated Drift is approximately 270 degrees Celsius (CRWMS M&O 1996b).

- A cool-down monitoring period which is expected to be comparable in duration to that of the heating period (although less time may be required for the Heated Drift to cool to ambient temperature). The power to the heaters will be ramped down at the conclusion of a constant heating phase as part of a controlled cooling period (CRWMS M&O 1996b).

- Post characterization activities to include removal of insulation, bulkheads, and selected instruments and test components; geophysical logging; permeability testing; mechanical testing such as plate loading, Goodman jack testing, pull testing and/or overcoring of rockbolts; coring of new boreholes; and possible overcoring of various existing boreholes for scientific purposes (Weaver 1999a).

6.12 HYDRAULIC FRACTURE TESTING

Hydraulic fracture testing involves the drilling of a nominally 30-m deep (100-foot) borehole nominally vertically downward and is described in Ricketts (1996). The controlling FWP is FWP-ESF-96-002 (YMP 1999b). Core samples are taken during drilling to determine the best locations in the borehole to perform the tests. Straddle-packer elements (water-inflatable packing bladders) are inserted above and below the zone to be fractured. The straddle-packer elements are pressurized, and then the test area in between (nominally less than two feet long) is pressurized with water until a fracture occurs. The test pump is shut off shortly after the fracture occurs, and the shut-in and decaying water pressures are monitored. This pressurization/depressurization cycle is repeated several times for additional data collection. Water flow-back quantities are recorded for each of the multiple pressurization/depressurization cycles.

Upon completion of data collection, the straddle-packer elements are depressurized and the test area is shifted to a new location in the borehole (generally several feet away from preceding test locations). Ricketts (1996) indicates that approximately five gallons of water are used at each location. The test is usually performed at approximately five locations in the borehole.

The final step in the hydraulic fracture testing is to perform a fracture impression-orientation test. In this portion of the test, impression packers are lowered to the locations of previously induced fractures and pressurized. The orientation of the impression packer is recorded before depressurization. The orientation and resulting hydraulic imprint on the impression packer are recorded on a transparent sheet.

Hydraulic fracture testing was conducted in the Alcove #5 and #6 Turn-Around Bays and at the end of the TTF AOD. An additional proposed site was in the TMA, but testing at this site is currently not scheduled. Hydraulic fracture testing has also been proposed at locations in the ECRB Cross Drift, but will be evaluated in a future revision to this DIE or another DIE. Other than traced water, no TFMs are lost during these tests.

6.13 GEOMECHANICS OF ROCK MASS STUDIES

6.13.1 Goodman Jack Testing

Subsurface geomechanics of rock mass studies (also known as Goodman Jack testing) includes the wet-drilling and sampling of NX-size boreholes as described in CRWMS M&O (1997b) and Lee (1997). The controlling FWP is FWP-ESF-96-002 (YMP 1999b). These boreholes are nominally 7.5 m in length and are used to perform geomechanics of rock mass studies to assist in the determination of geomechanical stability of the proposed repository rock. The boreholes are typically drilled in pairs, one horizontal and one vertical, to provide deformability data for all three dimensions. In selected locations the vertical downward boreholes are drilled to approximately 30 m in length to accommodate hydraulic fracture testing, as discussed above. Per Lee (1997), present testing locations include the Alcove #5, #6, and #7 Turn-Around Bays. (Additional boreholes and locations could be added if funding becomes available.)

Goodman jack testing involves deploying a 76-millimeter (mm) (3-inch) borehole jack which applies unidirectional pressure to the borehole wall by means of two opposed curved steel pistons, each covering a ninety degree sector over a length of approximately 20 cm (Lee 1997). Testing is performed in accordance with ASTM D4971.

6.13.2 Geotechnical Rock Properties Testing

Cored boreholes and slot cuts are being constructed in the TS Loop and the ECRB off the main tunnels to allow testing of geomechanical rock properties both in the underground environment and in the laboratory using cored materials (Weaver 2001b).

6.14 ECRB CROSS DRIFT TESTING

As discussed in Mitchell (1997e); Scott (1998), the following testing activities are conducted in the ECRB Cross Drift. Generally, testing activities conducted within the ECRB Cross Drift consist of dry drilling (using rock bolt drills), dry coring, air monitoring, bulk rock sampling techniques. ECRB Cross Drift testing also includes niche and alcove studies discussed in Section 6.10 above. The general testing activities are described in further detail in the other sections of this document and YMP (1997b, 1999b, 2000a, 2000b, 2000c). Ventilation system tests (e.g., simulated smoke or gas releases) may be performed to ensure system integrity or for validating emergency procedures. The following sections provide a general description of currently planned ECRB Cross Drift testing activities (other than ECRB niches and alcoves).

6.14.1 ECRB Cross Drift Moisture Studies

The major emphases of moisture studies in the ECRB Cross Drift are hydrologic testing and hazardous mineral (i.e., minerals having the potential to adversely impact waste isolation capabilities) assessment. The general activities associated with moisture flux studies are described in Section 6.10 and YMP (1999b, 2000c). Moisture Flux Studies were performed in Phase I of the ECRB cross drift. These tests also generated data used for confirming that the Phase II evaluation of potential waste isolation impacts herein, associated with water and organic material loss, are sufficient to bound Phase II ECRB Cross Drift activities. The ECRB systematic drill activities described in Mitchell (1999e) and YMP (2000c) will provide data on the hydrologic properties of the proposed repository rock. The following specific ECRB Cross Drift testing activities are planned in specified sections of the ECRB Cross Drift.

1. After TBM operation commenced, a single approximately 1.5-inch diameter by 2-m deep dry-drilled hole using one of the TBM-mounted rock drills was drilled about every 25 m of excavation of the ECRB Cross Drift. These boreholes were drilled into the left rib of the drift at a height accessible from the invert. An instrument package (heat dissipation probe) was placed in each of these boreholes by the PI as quickly as practical after the cutterhead exposes the rock matrix. This testing activity was conducted throughout the TBM-excavated portion of the ECRB Cross Drift.

2. After TBM operation commenced, a single HQ-sized by about 2-m deep dry-drilled/cored borehole was drilled at approximately 50-m intervals of the drift excavation. These boreholes were drilled/cored into the left rib of the drift at a height accessible from the invert using a core rig. Neutron logging is conducted in these boreholes at predetermined time intervals. This testing activity is throughout the TBM-excavated portion of the ECRB Cross Drift.

3. After TBM operation commenced, a single HQ-sized by about 6-m deep dry-drilled/cored borehole was drilled at approximately Station 5+00 m of the ECRB Cross Drift excavation. This borehole was also drilled/cored into the left rib of the drift at a height accessible from the invert using a core rig. Neutron logging is conducted in these boreholes at predetermined time intervals. This testing activity is conducted throughout the TBM-excavated portion of the ECRB Cross Drift beginning at approximately Station 10+00 and at approximately 500-m intervals thereafter.

4. Beginning at approximately Station 2+38 m, an approximate 50-m test area was established in which the constructor used water at an application rate that was calculated based on both machine optimization and dust abatement requirements. In this test area, three HQ-sized boreholes were dry drilled/cored in an array from a core rig mounted on a flat car. These boreholes were arranged such that one borehole was drilled/cored in each of the following configurations: (1) approximately 2 m deep into the left rib below springline, (2) approximately 6 m deep into the left rib above the invert, and (3) approximately 10 m deep into the bottom of the invert. These boreholes were drilled/cored immediately after the TBM trailing gear had passed. About one week later, a 15-m HQ-sized dry-drilled/cored borehole was drilled/cored into the bottom of the invert in the same array. Cores were collected, and neutron logging is conducted in these boreholes at predetermined time intervals. The primary testing activity for these boreholes is discussed and evaluated in CRWMS M&O (2000a) and is not evaluated in this DIE. However, ongoing moisture studies conducted in these boreholes are evaluated by this DIE.

5. Beginning at approximately Station 2+88 m, an approximate 50-m test area was established in which the constructor used an approved organic surfactant during TBM operations. In this "test area," three HQ-sized boreholes were dry drilled/cored in an array from a core rig mounted on a flat car or on the TBM. These boreholes were arranged such that one borehole was drilled/cored in each of the following configurations: (1) approximately 2 m deep into the left rib below springline, (2) approximately 6 m deep into the left rib above the invert, and (3) approximately 10 m deep into the bottom of the invert. These boreholes were drilled/cored immediately after the TBM trailing gear had passed. About one week later, a single 15-m HQ-sized dry-drilled/cored borehole was drilled/cored into the bottom of the invert in the same array. Cores were collected, and neutron logging is conducted in these boreholes at predetermined time intervals. The primary testing activity for these boreholes is discussed and evaluated in CRWMS M&O (2000a) and is not evaluated in this DIE. However, ongoing moisture studies conducted in these boreholes are evaluated by this DIE.

6. Small drainage bench tests are planned throughout the ECRB Cross Drift. YMP (2000c) describes a series of these drainage bench tests that involve the excavation of approximately 1-m long by 1-m wide by 0.5-m high openings on the left rib or the ECRB Cross Drift. The amount of LiBr traced construction water is to be minimized during construction of these openings. These small openings allow for testing with nominally 24-inch diameter infiltration rings where controlled quantities of traced water will be applied. Per YMP (2000c), the TCO will provide appropriate signage and protection to ensure the tests are properly protected. Furthermore, the final bench locations are coordinated between the PI(s) and TCO so as to ensure negligible test interference.

7. Systematic hydrologic characterization testing is planned throughout sections of the ECRB Cross Drift. These tests are designed to measure the seepage potential, address the impact of spatial variability of fracture flow and transport properties, as

well as the influence of mechanical deformation due to drift openings seepage and drainage. One such test (between approximate ECRB Stations 14+44 m and 17+63 m) is described in Mitchell (1999e) and YMP (2000c) and involves the drilling and testing of approximately 19 HQ-3 size, 20-m long boreholes. Approximately 6 of these boreholes will be drilled in horizontal pairs, about 2 to 3 m apart, at approximate 90-m intervals off the rib of the ECRB Cross Drift. Cross hole air-injection testing using SF_6 and selected noble gases (i.e., Krypton, Neon, and Xenon) for fracture flow connectivity and gas tracer testing for effective fracture porosity are planned in each borehole pair. Approximately 3 near vertical boreholes at approximate 90-m intervals off the crown of the ECRB Cross Drift are planned for packed interval air permeability testing. The remaining boreholes (approximately 10) will be drilled approximately 15 degrees (upward) off horizontal and aligned with the ECRB Cross Drift. These boreholes will be collared on the ECRB Cross Drift crown and dry-drilled such that the boreholes will be a few meters above the ECRB Cross Drift crown at their terminus.

Borehole scanning, air permeability test, and pulse liquid releases have been proposed for these boreholes. Per Mitchell (1999e), the test equipment planned to be used for this activity includes: mass flow controllers; pressure transducers; tracer handling, air, or liquid injection/release systems; sample collection systems; mass spectrometer(s); and data collection and management systems (which are planned to be connected to the fiber optic system currently in the Subsurface ESF).

Per Mitchell (1999e), the pulse liquid tracer testing would involve the release of traced water (using approved tracers) in four to five packed-off sections of the slanted boreholes. The crown of the ECRB Cross Drift will be monitored for seepage. The following tracers have been requested for release during the ECRB Systematic Drilling activity:

- FD&C Blue No. 1 (food color)
- FD&C Red No. 40 (food color)
- FD&C Yellow No. 5 (food color)
- FD&C Yellow No. 6 (food color)
- Amino G Acid
- Fluorescein
- Lissamine (Acid Yellow No. 7)
- Pyranine
- Rhodamine B Sulfo
- 2,3-Diflurobenzoic Acid
- 2,4-Difluorobenzoic Acid
- 2,5-Difluorobenzoic Acid
- 2,6-Difluorobenzoic Acid
- 3,4-Difluorobenzoic Acid
- 3,5-Difluorobenzoic Acid
- 2,3,4-Trifluorobenzoic Acid
- 2,3,6-Trifluorobenzoic Acid

- 2,4,5-Trifluorobenzoic Acid
- 2,4,6-Trifluorobenzoic Acid
- 2,3,4,5-Tetrafluorobenzoic Acid
- 2,3,4,6-Tetrafluorobenzoic Acid
- Pentafluorobenzoic Acid
- Sodium Chloride
- Lithium Bromide
- Sodium Iodide

The maximum volumes and concentrations of these tracers requested for release in the ECRB Systematic Drill activity are 25,000 liters (about 6,605 gallons) at a concentration up to approximately 0.0004 grams per liter (0.4 ppm) for fluorescent dyes, 20,000 liters (about 5,284 gallons) at a concentration up to approximately 0.02 grams per liter (20 ppm) for food color dyes, 65,000 liters (about 17,173 gallons) at a concentration of approximately 0.02 grams per liter (20 ppm) for Fluoride organics (i.e., Di, Tri, Tetra, and Pentafluorobenoic Acids), 5,000 liters (about 1,321 gallons) at a concentration of approximately 0.005 grams per liter (5 ppm) for sodium iodide, 5,000 liters (about 1,321 gallons) at a concentration of approximately 0.4 grams per liter (400 ppm) for sodium chloride, and 5,025 liters (about 1,328 gallons) at a concentration of approximately 1 grams per liter (1,000 ppm) for LiBr in excess of the 20 ± 10 ppm allowed for tracing construction water.

8. Thermal conductivity measurements may be conducted in the ECRB Cross Drift. Multiple boreholes, 10 to 15 m deep, would be dry-drilled from the left rib approximately one meter or greater above the invert from ECRB Stations 14+40 to 17+63 m. Future drilling may extend beyond Station 17+63 m. (Weaver 2001a)

9. Throughout ECRB Cross Drift construction activities, construction support will be requested by the TCO to install simple hangers for testing instrumentation including temperature, humidity, and air monitoring stations. Periodically, the TCO may request that the conveyor belt be stopped temporarily to collect muck samples.

6.14.2 Other ECRB Cross Drift Testing

Construction monitoring, consolidated sampling, perched water testing, geologic mapping, and other systematic testing are conducted where applicable in the ECRB Cross Drift. These activities are described in the other sections of this DIE and are sufficiently similar to that testing such that they may be evaluated together. Therefore, other than those ECRB Cross Drift tests specifically evaluated separately (i.e., niches, alcoves, and moisture studies), there are no other planned ECRB Cross Drift testing activities that require evaluation.

In addition to testing described above, testing referenced in Weaver (1999b) will be conducted near the proposed opening of Niche #5 in the ECRB Cross Drift to determine the effects of drill-and-blast excavation on air-permeability measurements. Three approximately 20 m long, dry cored, horizontal boreholes will be excavated in the left rib of the ECRB Cross Drift near the perimeter of the breakout for Niche #5 (approximate ECRB Station 16+20 m). These boreholes will be used for air-permeability measurements and blast effects monitoring both before and after the excavation of ECRB Niche #5. Similar testing may be performed in the vicinity of Alcove

#8 and/or Niche #6. No TFMs other than approved gases are planned to be permanently emplaced for these tests.

6.14.3 Cross Drift Thermal Testing (CDTT-Alcove 10)

This testing is focused on the Topopah Spring lower lithophysal (Tptpll) unit with the primary objective of observing how the liquid water from the condensation of rock pore-water vaporized by heat, travels through the rock, and whether liquid water can penetrate through a volume of rock heated to above 100^0C. Observations in the CDTT on the movement of heat-driven water in Tptpll are expected to confirm the premise that water mobilized by the decay heat from the emplaced waste will drain by gravity through the cooler central regions of the pillar between the drifts to below the emplacement horizon.

A block of rock in the Tptpll unit will be exposed by excavating an L-shaped alcove off the left rib of the ECRB Cross Drift. The rock will be heated by 5-meter long rod heaters placed in parallel holes in a horizontal plane. With the progress of heating, the moisture in the rock surrounding the heaters should be driven off, and a roughly cylindrical volume of dry rock should develop and grow around each heater. The water from the dried rock should be driven by the heat in all directions and should condense as the vapor reaches the cooler regions away from the heaters. The condensed liquid should drain down by gravity via the fractures and other openings in the rock.

Collection holes, which are parallel and perpendicular to the heaters, will be located below the heater plane. These holes are strategically placed immediately below the anticipated boiling zone around the inner heaters, and are designed to intercept any liquid water that may travel to them. Samples of any water collected in these holes may be analyzed in the laboratory.

Tiltmeters capable of recording rock movement of extremely small magnitude will be installed in drillholes. The tiltmeter measurements will enable the displacement field caused by the thermal expansion of the heated block to be delineated. This information and the measured temperature field can be used to quantify the coefficient of thermal expansion of the rock mass.

Probes to monitor microseismic or acoustic emissions may be installed in several holes. The probes may be installed prior to alcove excavation so that microseismic activities caused by the excavation process may be recorded.

It is planned the heating in the CDTT will be maintained for 9 to 12 months. Toward the end of the heating period, after approximately seven-and-a-half months of heating, water will be released in measured quantities in the injection hole. Water will be released at intervals of 7 to 10 days and its movement through the various sectors of rock heated to different temperatures will be tracked. (YMP 2001)

6.15 INFILTRATION/PERCOLATION MONITORING BOREHOLES

Infiltration/percolation monitoring involves the drilling of short (nominally less than 30 m long) boreholes vertically downward (typically within 10 degrees of vertical) from the ESF invert. The objectives of these tests are to monitor the infiltration/percolation of liquids below the ESF and are implemented in FWP-ESF-96-004 (YMP 2000c). As indicated in Mitchell (1997e), the proposed tests are conducted at three locations along the TS Main Drift. The infiltration/percolation monitoring boreholes in the TS Main Drift are single downward boreholes at each location. A process similar to that used for placement of convergence pins holes is used to penetrate the inverts at the proposed locations. A drill rig is used to extend the borehole to the desired depth. Testing locations are selected due to their higher than average water exposure during ESF construction and to limit their impacts to ongoing construction activities (i.e., so as to not interfere with the Heated Drift testing activities).

Per Mitchell (2000a), two vertical downward boreholes in Alcoves #3 and #4 will be used for additional infiltration/percolation monitoring. Instrumentation consisting of heat dissipation probes and tensiometers will be installed in the boreholes. The instrumentation will be confined in the boreholes with a mixture of Overton type sand and Bentonite clay plugs, encased in a PVC pipe. No additional water is planned to be added to these boreholes.

Three ECRB Starter Tunnel infiltration/percolation monitoring boreholes vary slightly from those in the TS Main Drift. These boreholes are located at the end of the ECRB Starter Tunnel just ahead of the launch point of the ECRB TBM. These holes are angled underneath the TBM excavation path, and are instrumented more heavily than the TS Main Drift boreholes. They monitor liquid infiltration/percolation immediately below the TBM operation area. Additional, near-vertical boreholes similar to those in the TS Main Drift drilled in the ECRB Cross Drift, before crossing the TS Main Drift.

6.16 GROUND SUPPORT IN THE VICINITY OF FAULT ZONES

Hollins (1997c) describes the extended excavation of the Southern Ghost Dance Fault Alcove (SGDFA, Alcove #7). Videos of borehole ESF-SAD-GTB#1 were used to explore ahead of the excavation in Alcove #7, and core samples from that borehole were also used to identify two strands (i.e., splays) of the Ghost Dance Fault (GDF) in the region of Alcove #7. The first strand encountered was the Western GDF strand at approximately Station 1+67 m from the centerline of the TS Main Drift. The second is the Eastern GDF strand at approximately Station 1+98 m from the centerline of the TS Main Drift. The TCO indicated that there was a need to conduct testing in the vicinity of these fault locations and that the use of dry-drilling and the prohibition of the use of Swellex rockbolts was desired.

6.17 TEMPORARY TESTING BULKHEADS

Temporary bulkheads are installed in support of various testing activities for selected underground locations. These bulkheads (not including the TTF Heat Drift bulkhead discussed above) are used to isolate a section of the ESF (primarily in alcoves) to conduct testing. Two bulkheads were also installed in the ECRB Cross Drift at approximated ECRB Stations 17+63 and 25+03 to isolate a large section of the drift for an approximate 1-year duration. Additionally, a refuge station may be constructed at ECRB Station 17+59 (Schulenburg 2000). A third bulkhead was installed beyond the second bulkhead (i.e., beyond Station 25+03) to better isolate the test area (Peters 2000). The installation of the bulkheads (similar to the niche study bulkheads discussed above) is coordinated with the TCO and appropriate PIs. Erection of a bulkhead typically involves installation of a steel set to which the bulkhead is attached. The steel set is typically sealed to the excavated rock surface using a wire mesh and shotcrete combination.

Sodium silicate may also be used to improve the sealing around the bulkheads. The goal is to achieve a near airtight seal at the point of bulkhead installation. The bulkheads are provided with penetrations for access doors and cableways as required. These bulkheads are considered temporary and will be removed before Repository operation. (CRWMS M&O 1997g; Peters 2000)

6.18 ALCOVE #2 EXHIBIT AREA

Alcove #2, also known as the Bow Ridge Fault Alcove, is located on the right rib of the TS North Ramp at approximately Station 2+00 m. The alcove was constructed to conduct hydrologic testing within the nearby Bow Ridge Fault (which is located at approximately Station 2+20 m of the ESF North Ramp). Instrumentation packages are currently installed in nominally horizontal boreholes that emanate from the left rib of the alcove (at about five and eight meters from the end of the alcove). Instrument readouts are obtained periodically.

As described in Ricketts (1997) and YMP (1997e), Alcove #2 was converted for use as an exhibit area. An elevated, steel walkway was erected along the right rib of the North Ramp to allow visitor access. The walkway extends from the approximate location of the North Portal (or Alcove #1 area) to the entrance of Alcove #2. A similar, second elevated walkway (of approximately 30 m in length) may also be erected along the TS North Ramp from Alcove #2 to the location of the fault. This walkway would allow visitors the opportunity to observe the Bow Ridge Fault. These walkways may be freestanding (i.e., not connected to the existing steel sets) or may attach to the steel sets using clamps or bolts through existing bolt holes. No new holes are to be drilled in the steel sets, and no welding on the steel sets will be performed. The walkways are considered temporary and are erected such that they are removable.

Handrails were also erected inside Alcove #2 to define the visitor area and to prevent visitor access to the testing borehole collars and associated instrumentation. A full or partial concrete slab floor was also installed. Improved lighting (i.e., approximately 36 lighting fixtures and emergency lighting fixtures) and ground support were added, as well as a podium and a sound system. Ventilation enhancements (i.e., a new fan [with silencer] and additional ductwork) was installed. The electrical system was expanded as necessary to support these additional electrical loads. Various exhibits and hands-on demonstrations were placed in the exhibit area. Access for visitors is restricted to periodic guided tours only. (Ricketts 1997; YMP 1997e)

6.19 BUSTED BUTTE TESTING

The UZ Transport Test at Busted Butte is located to the south-southeast of the TS Loop (approximately 3.3 miles from the South Portal) and is outside the CCAB. Although, not a part of the TS Loop, the proposed testing is a subsurface testing activity and is controlled by FWP-ESF-97-002 (YMP 1999e). These construction and testing activities provide access to the CH geologic structure and are described in YMP (1999e). The Busted Butte Test includes a construction phase, three test phases, and a completion or decommissioning phase. The actual testing activities are subject to future budget and scientific constraints, such that all three phases of testing may not be performed.

The construction phase described in YMP (1999e) included road enhancements, highwall and pad construction, and excavation of an approximately 60-m-long drift. The excavation was accomplished by drill-and-blast. Additional excavation by mechanical means is also possible for mineback operations. The initial section of the drift is nominally 3 m in diameter with the final approximately 25 m (i.e., the drill bay or test room section) being nominally 5 to 7 m in diameter. An additional drill bay was excavated off the right rib near the middle of the test room section to provide access to a second face of the test block(s). The drift originates in the lower vitrophyre and was excavated to penetrate the entire layer of the CH formation. The minimum ground cover above the test block is approximately 15 to 20 m.

YMP (1999e) describes three distinct and separate testing phases. In the first phase, a series of approximately eight nominally two-meter-deep boreholes are dry-cored along the left rib of the drift. These boreholes are used to: (1) collect core samples for analysis, (2) install moisture monitoring equipment, and (3) carry out initial tracer tests. This initial phase was planned for approximately five to six months with overcoring of the two-meter-deep boreholes at the end of testing to provide preliminary transport data. In cases where some or all of the sorptive tracers migrated imperceptibly from the injection source, the overcoring allows the determination of the detailed spatial distribution of the tracers via laboratory analysis. Microspheres were used in the boreholes to determine the movements of colloids associated with a liquid front into partially saturated tuffs.

The first phase of testing includes limited mineback operations and overcoring. Mineback operations involve spading off in 30 to 50 cm intervals. The mineback volume will be approximately four meters wide by four meters high by two to three meters deep. A steel-reinforced shotcrete pillar will be used on either side of the test area for support. There are about four overcores planned. (YMP 1999e)

The first phase of testing includes monitoring of the humidity, barometric pressure, and temperature of the air in the main drift began as soon as possible after excavation and will be continued throughout the course of operations. These data, together with instrumentation in boreholes, are used to assess whether perturbations from the main drift are negligible over the testing time frame. In addition, at least one approximately one meter cube of CH rock was removed for off-site testing. Concurrent geologic, hydrologic, and geochemical laboratory tests were conducted to complete scoping calculations for the second test phase. (YMP 1999e)

YMP (1999e) describes the second phase of the testing as including the dry-coring of about 28 boreholes approximately 10 m deep to allow for injection and monitoring of tracers in a test block. These holes consisted of 10 injection holes, 12 collection holes, and ERT holes. Collection boreholes were distributed so as to intercept potential tracer pathways as determined from the first phase data collected and modeling performed. These boreholes were configured to activate the largest possible volume of the second phase test block and accommodate the transport scaling test. Among other methods, video, neutron, and air permeability logging were performed pretest. ERT, neutron logging, and penetrating radar methods are used to assess the tracer front progression at selected time intervals. Microspheres are being used in the tracer solutions to simulate the movements of colloids associated with the liquid front into partially saturated tuffs. Chemicals (analogues of radionuclides) are being injected and collected to determine unsaturated hydrologic properties of the tuffs at the Busted Butte test facility. The advance of the tracer plume is also monitored within the test block using the geophysics methods described above, as well as neutron logging and collection pad analyses. Concurrent geologic, hydrologic, and geochemical laboratory tests are conducted throughout the second phase so as to complete scoping calculations for third test phase. This approach is intended to allow time for the new data to be processed such that it can be used in the process models that support License Application and Total-System Performance Assessment (TSPA) activities. The first two phases of testing characterize unsaturated tracer testing zones.

At the completion of the injection portion of the second phase, a partial mine-back operation may be performed to get a detailed picture of the three-dimensional tracer distribution within the test block. This would allow validation of the various geophysical methods used to evaluate the tracer movement during the test. The faces of the mine-back would be surveyed, photographed using normal and black light sources, mapped, and sampled to provide the tracer distribution throughout the block. A mine stability evaluation and design would be conducted prior to the mine-back to ensure a safe operation. Necessary ground support would be added prior to (if necessary) and during this excavation operation based on safe mining procedures and the ground support evaluation and design (YMP 1999e). CRWMS M&O (2000d) provides additional details on the mineback of this second phase of testing at Busted Butte.

The final phase of the testing, if implemented, includes air injection (i.e., pneumatic) testing is performed initially to identify potential "fast pathways" within the second test block before initiating saturated-tracer tests. The purpose of these tests is to characterize the rock in the vicinity of the second test block and to determine the variability of flow rates that might be encountered in the tuff units, under partially saturated conditions. Approximately 28 boreholes approximately 10 m deep would be dry-cored in a fashion similar to the second phase of testing described above. Single hole tests provide a measure of the permeability variation along the boreholes and crosshole packer tests measure the air flow through the rock mass and identify any possible pneumatic "fast pathway" between the boreholes. Following this pneumatic characterization of the test block, locally saturated transport tests are conducted in the boreholes using a different set of tracers from those used in the unsaturated tests and, thus, differentiate the tests. Microspheres may be used in the boreholes to simulate colloid movement in CH. Extensive continuous and/or pulse injections of conservative and nonconservative liquid tracer mixtures are used. The saturated tests involve faster water fluxes and, therefore, affect a larger area than the unsaturated transport tests. This testing phase concludes with overcoring and/or a partial mineback of the second test block. Concurrent geologic, hydrologic, and geochemical laboratory tests are conducted throughout this phase, and the results are integrated with the previous testing phases. (YMP 1999e)

The completion or decommissioning phase described in YMP (1999e) includes test close-out, demobilization, and reclamation activities. The tracers and other TFMs proposed for use in the Busted Butte UZ Transport Test are included in Attachment II. These include the additional TFMs requested in Brake (1998b).

6.20 TFM USE

TFM usage has been discussed in the text of Sections 6.1 through 6.19, as appropriate. For TFMs that were not specifically/individually discussed in Sections 6.1 through 6.19, CRWMS M&O (1999a) has previously evaluated an extensive list of TFMs that are approved for use in the Subsurface ESF. Attachment II contains a comprehensive list of TFMs (i.e., a list of TFMs that have been either previously evaluated by CRWMS M&O (1999a, 2000a), or specifically evaluated by subsequent sections of this DIE), which are approved for use in subsurface testing-related activities evaluated herein. However, the Attachment II TFMs are approved for use in these testing activities, provided their use and quantities are consistent with the restrictions established in Section 13.3 and Attachment II of this DIE.

Per Assumption 4.4, the use of TFMs is controlled by the requirements of the TFM procedure (AP-2.17Q). The use of any TFM within the Subsurface ESF that is not listed in Attachment II requires an evaluation per AP-2.17Q, before its use. However, only those TFMs that are permanently committed within the Subsurface ESF are required to be reported per the requirements of AP-2.17Q.

7. EVALUATED CONDITIONS

The following potential events and activities were considered for evaluation: earthquakes, rockfall, use of and inadvertent spills of oil and other fluids, fires, explosions, ground water inflow, and use of water and compressed air. These events and activities are used to evaluate the temporary items discussed above (Section 6) using the criteria in NLP-2-0.

Fires and explosions are evaluated with regard to potential impacts. Disruption of items as a result of earthquakes, fire, and explosions are not specifically evaluated in this DIE; however, deterministic failure of systems and components is used to assess the potential impacts on site characterization activities and waste isolation.

Given the DIE Requirements discussed below for spill protection/containment and clean-up of released fluids, the quantities of committed fluids (other than water) retained at the site from any credible equipment or vehicle accident or failure are expected to have negligible impacts on waste isolation and site characterization testing. In addition, the reporting of any committed fluids resulting from a spill, with subsequent evaluations of potential impacts to site characterization and waste isolation capabilities from those fluids, enables identification of any additional controls which may be appropriate to minimize potential impacts from accidental losses of such fluids. CRWMS M&O (1999a) includes an evaluation of the larger quantities of fluids (other than water) used by underground equipment.

8. AFFECTED Q-LIST ITEMS

8.1 PROXIMITY TO PROPOSED REPOSITORY AND CONCEPTUAL CONTROLLED AREA BOUNDARY

8.1.1 TS Loop

The TS Loop construction progresses westward from the Starter Tunnel (elevation ≈1120 m), south through the TS Main Drift along one edge of the primary WE areas (elevation ≈1067 m), and then eastward where it terminates at the South Portal at approximately Station 78+77 m (elevation ≈1160 m). The ESF Ramps (North and South) and TS Main Drift will provide access to the potential repository. Any construction effects will be incorporated into the design of the potential repository.

CRWMS M&O (1996c) lists existing and planned boreholes in the vicinity of the TS Loop. Surface-based site characterization tests range from surface geologic mapping and sampling, to the drilling and instrumentation of boreholes to water table depth and greater. Surface-based tests with potential sensitivity to the underground construction and/or testing activities are those tests conducted within the unit being penetrated by the TBM and tests sensitive to vibrational and energy fields created by construction equipment. An evaluation of potential impacts on site characterization testing (including surface-based testing) is included in Section 10.

Approximately 40 tests are or have been previously planned for the Subsurface ESF. Test Planning Package 91-5 (YMP 1992) provided a relatively comprehensive preliminary listing of these tests, including tests not defined in the Site Characterization Plan. A number of these tests are no longer planned or have been completed. In general, testing associated with previously constructed alcoves or alcoves under construction is scheduled for completion. However, the possibility exists that certain deferred tests could be required in the future, perhaps in response to the requirements of regulatory agencies or to other changing programmatic requirements. Thus, a conservative approach, one in which reasonable efforts are taken to minimize changing the general characteristics of the TS Loop and surrounding rock, is advantageous. The M&O TCO has examined the testing requirements and identified potential construction constraints for each test in Test Planning Package 91-5 (YMP 1992). These constraints were later incorporated into the ESFDR (YMP 1997a).

8.1.2 ECRB Cross Drift

The ECRB Cross Drift construction begins with a breakout in the left rib at about Station 19+92 m and at approximate elevation 1082 m along the ESF North Ramp (CRWMS M&O 1998b). The ECRB Cross Drift Starter Tunnel trends southwestward (at an approximate centerline azimuth of 254 degrees) to approximately Station 0+26 m. From approximately Station 0+26 m, the TBM excavates along the same approximate 254 degree centerline azimuth to about Station 1+82 m. At approximately Station 1+82 m of the ECRB Cross Drift, the TBM begins a turn to the left and at approximately Station 3+15 m, it reaches an approximate centerline azimuth of 229 degrees and continues to approximately Station 7+73 m, a point just before crossing over the TS Main Drift (CRWMS M&O 1998b). The section of the ECRB Cross Drift from approximately Station 0+26 m to Station 7+73 m is referred to as Phase I of the ECRB Cross Drift.

After crossing the TS Main Drift, the ECRB Cross Drift excavation continues along the same 229 degree centerline azimuth at approximately 15 m to 20 m above the potential WE zone of the repository block (CRWMS M&O 1997a). At approximately Station 23+20 m of the ECRB Cross Drift, the TBM begins a turn to the right and at approximately Station 26+40 m, it reaches an approximate centerline azimuth of 289 degrees (CRWMS M&O 1998b). Excavation continues on this heading until the ECRB Cross Drift termination point of approximately Station 28+23 m. The terminus of the ECRB Cross Drift is approximately 50 m west of the western most strand of the Solitario Canyon fault (Hollins 1997d). The section of the ECRB Cross Drift from approximately Station 7+73 m to its terminus is referred to as Phase II of the ECRB Cross Drift. A discussion of the hydrologic and geologic conditions (i.e., of the potential repository's natural barrier) that are encountered by the ECRB Cross Drift is included in Section 9 of this DIE, including elevations and locations.

8.1.3 Proximity to Planned and Existing Boreholes

Hollins and Mitchell (1997) lists existing and planned boreholes in the vicinity of the ESF. Surface-based testing (SBT) site characterization activities range from surface geologic mapping and sampling to the drilling and instrumentation of boreholes at water-table and greater depths. SBT activities with potential sensitivity to the underground construction and/or testing activities conducted in the ESF are: (1) tests conducted in proximity to the hydrogeologic unit penetrated by the TBM and (2) tests sensitive to mechanical vibration, mechanical stress, and/or the electromagnetic fields created by electrical equipment used in ESF. An evaluation of potential impacts on site characterization testing (including SBT) is included in Section 10 of this DIE.

8.1.4 Test Coordination and Control

In the development of the ESF construction schedule, the TCO ensured that accessibility to testing opportunities was maintained while the TBM(s) was operating or other excavation methods were occurring. Although the purpose of the tunnel is to provide the opportunity to test in more representative conditions than can be provided by surface outcrops, the opening of the tunnel has introduced surface atmospheric conditions to a volume of rock where *in situ* data are desired. For example, an anticipated temporal lag (between the time of tunnel excavation and the time when the tunnel effect is transmitted into the rock mass) is the window of opportunity in which certain planned tests are staged. In these cases, the deferral of testing until construction is complete could result in biasing the test results in an undetectable and unpredictable way (see Section 10). Access for testing must also be provided to assure the timely collection of data for Viability Assessment and Site Recommendation (DOE 1996).

In developing controls specific to the TS Loop and ECRB Cross Drift, this evaluation incorporates design and/or construction constraints identified in the ESFDR (YMP 1997a) with regard to the interface between testing and various excavation activities. Thus, this evaluation does not include testing-related activities that occur in the test support areas after the area is constructed and the testing accommodations have been installed. Specific construction constraints applicable to the fielding of the tests, such as whether tracer gas is required in the drilling of hydrochemistry boreholes, will be addressed in the individual DIEs and FWPs for those activities.

8.2 POTENTIALLY AFFECTED Q-LIST ITEMS

The proposed activities will affect the Timber Mountain Tuff, TCw, PTn and TSw hydrogeologic units. Additional underlying hydrogeologic units may also be affected, depending on the quantity and behavior of the applied construction water and TFMs. The TCw, PTn and TSw hydrogeologic units are on the Q-List (YMP 1998a). In addition, the engineered items on the Q-List (YMP 1998a) that may be affected include the Underground Excavations, the Waste Ramp or the Tuff Ramp, and the Seals. The planned excavation activities may affect permanent items including ground support and underground openings.

9. EXPECTED CONDITIONS

The TS Loop of the ESF excavation is entirely in the UZ, beginning at an elevation of about 1120 m at the North Portal, minimizing at an elevation of about 1067 m near the transition from the North Ramp to the TS Main Drift, and emerging at an elevation of about 1160 m at the South Portal (CRWMS M&O 1995b). The water table under the TS Loop is nearly flat and lies at an elevation of approximately 730 m (Robison et al. 1988). Therefore, the water table lies approximately 430 m below the top of the South Portal, approximately 390 m below the top of the North Ramp and approximately 337 m below the minimum in the TS Loop near the North Ramp/Main Drift transition.

The ECRB Cross Drift excavation is also entirely in the unsaturated zone, beginning from the left rib of the ESF North Ramp at approximately Station 19+92 m at an elevation of about 1082 m, crossing (at an elevation of about 1093 m) approximately above Station 30+61 m of the TS Main Drift, proceeding through the potential repository block (above the potential WE zone) to an elevation of about 1114 m, and ending at an elevation of about 1103 m at approximately Station 28+23 m of the ECRB Cross Drift (CRWMS M&O 1998b). The water table under the portion of the ECRB Cross Drift, located east of the TS Main Drift, is nearly flat and lies at an elevation of approximately 730 m (CRWMS M&O 1997h; Robison et al. 1988). To the west of the TS Main Drift, the water table rises from approximately 730 m to about 770 m at the termination point of the ECRB Cross Drift (CRWMS M&O 1997h; Robison et al. 1988). Therefore, the water table lies approximately 352 m below the ECRB Cross Drift Starter Tunnel and approximately 333 m below the western end of the ECRB Cross Drift.

9.1 SIGNIFICANT GEOLOGIC FEATURES

The ESF TS Loop excavation is discussed in Albin et al. (1997); Barr et al. (1996); Beason et al. (1996); Eatman et al. (1997); CRWMS M&O 1995b relative to the major geologic strata in terms of both the revised lithostratigraphic nomenclature and the thermal/mechanical (TM) nomenclature for the rock units used in the 3-D site model by the United States Geologic Survey (USGS). The ECRB Cross Drift excavation begins within the TS Tuff upper lithophysal (Tptpul) of the Paintbrush Group and ends within this same unit (west of the Solitario Canyon fault) after crossing through the crystal-poor, middle nonlithophysal (Tptpmn), crystal-poor, lower lithophysal (Tptpll), and the crystal-poor, lower nonlithophysal (Tptpln). The lithostratigraphic units along the TS Loop and ECRB Cross Drift include three groups (in descending order): the Timber Mountain Group; the Paintbrush Group, which includes five ash flow tuffs separated by bedded tuffs; and the Crater Flat Group.

Yucca Mountain Lithostratigraphy:

> The Timber Mountain Group is comprised of the Rainier Mesa Tuff (Tmr) and pre-Rainier Mesa Tuff bedded tuff (Tmbt1) within the TS Loop.
>
> In order of descending stratigraphy, the Paintbrush Group includes:
>
>> Tuff Unit "X" (Tpki)
>>
>> Pre-Tuff Unit "X" bedded tuff (Tpbt5)
>>
>> Tiva Canyon Tuff (which is broken into three units: crystal-rich--Tpcrv; undifferentiated, devitrified--Tpcun; and crystal-poor, vitric, nonwelded--Tpcpv)
>>
>> Pre-Tiva Canyon Tuff bedded tuff (Tpbt4)
>>
>> Yucca Mountain Tuff (Tpy)
>>
>> Pre-Yucca Mountain Tuff bedded tuff (Tpbt3)
>>
>> Pah Canyon Tuff (Tpp)
>>
>> Pre-Pah Canyon Tuff bedded tuff (Tpbt2)
>>
>> Topopah Spring Tuff (which is broken into eight units: crystal-rich, vitric, non- to moderately welded--Tptrv; crystal-rich, devitrified, nonlithophysal--Tptrn; crystal-poor, upper lithophysal--Tptpul; crystal-poor, middle nonlithophysal--Tptpmn; crystal-poor, lower lithophysal--Tptpll; crystal-poor, lower nonlithophysal--Tptpln; crystal-poor, densely-welded subzone--Tptpv3; and crystal-poor, vitric, non-to moderately welded--Tptpv1 and Tptpv2),
>>
>> Pre-Topopah Spring Tuff bedded tuff (Tpbt1).
>>
>> In order of descending stratigraphy, the Crater Flat Group consists of the CH Formation (Tac) and the Prow Pass Tuff (Tcp), both of which contain basal bedded tuffs.

The lithostratigraphic units outlined above are grouped into TM units by the USGS, which are summarized in CRWMS M&O (1995b). Because the TM units are based on properties that result from processes in addition to petrogenesis, the boundaries of these units do not correspond directly to formational boundaries but do, in general, correspond to rock unit boundaries. In order of descending stratigraphy the TM units are:

Undifferentiated overburden (UO) that includes the Tmr, Tmbt1, Tpki, Tpbt5, and Tpcrv;

Tiva Canyon welded unit (TCw) that is equivalent to the Tpcun;

Upper PTn comprised of the Tpcpv, Tpbt4, Tpy, Tpbt3, Tpp, Tpbt2, and Tptrv;

Topopah Spring welded, lithophysae-rich unit (TSw1) that includes the Tptrn and Tptpul;

Topopah Spring welded, lithophysae-poor unit (TSw2) that includes the Tptpmn, Tptpll, and Tptpln;

Topopah Spring welded, vitrophyre (TSw3) that is equivalent to the Tptpv3; and

Lower Topopah Spring non-welded unit and Calico Hills Tuff (CHn) that is comprised of the Tptpv1, Tptpv2, Tpbt1, Tac, and Tcp.

9.2 SIGNIFICANT HYDROLOGIC FEATURES

The TM units given above are closely related to the hydrogeologic units and the designators used here to refer to the hydrogeologic units are taken to refer to the corresponding TM units given above: TCw--Tiva Canyon welded, PTn--Paintbrush nonwelded, TSw (1,2,3)--Topopah Spring welded, and CHn--Calico Hills nonwelded. Because information concerning the thickness and extent of the basal Tiva Canyon units (Tpcpv and Tpbt4) and Topopah Spring caprock (Tptrv) zones is not available in all cases, the PTn hydrogeologic unit in this report will be defined to consist of, at a minimum, the Yucca Mountain and Pah Canyon members of the Paintbrush Tuff (Tpy, Tpbt3, Tpp, and Tpbt2).

Distances to geologic and hydrologic features along the TS Loop and ECRB Cross Drift (as measured along the tunnel excavation) and the minimum distance from each geologic and hydrologic feature to potential WE areas (i.e., minimum offsets from potential WE areas) are given in Table 9.1 for the TS Loop and in Table 9.2 for the ECRB Cross Drift (Albin et al. 1997; Barr et al. 1996; Beason et al. 1996; Eatman et al. 1997). The spatial relation between the TS Loop/ECRB Cross Drift and the current conceptual design of the potential repository is discussed in CRWMS M&O (1995c, 1997h).

The TS Main Drift is a minimum of 37 m from potential WE zones within the primary emplacement area. Potential expansion areas (DOE 1986) that may be used as part of the potential repository lie beneath the North Ramp west of the Bow Ridge Fault and beneath the entire South Ramp, however, the current design of the potential repository does not include these expansion areas. The closest potential WE zone within the expansion areas under the North and South Ramp is assumed to be within middle nonlithophysal zones of the TS Formation (Tptpmn), which constitutes the top of the TSw2 (CRWMS M&O 1995c).

Table 9.1. Geologic and Hydrologic Features along the ESF TS Loop.

Geologic/Hydrologic (G/H) Feature	Distance From North Portal Headwall Of G/H Feature (M)	Minimum Distance From G/H Feature To Potential Waste Emplacement Area (M)
North Ramp		
Tiva Canyon Tuff (Tpcpul, Tpcpmn, Tpcpll)	0 - 200	268
Bow Ridge Fault	200	268
Pre-Rainier Mesa Tuff	202 - 263	255
Tuff Unit "x"	263 - 335	245
Tiva Canyon (TCw)	335 - 750	173
Imbricate Fault Zone	470 - 2800	37
PTn	750 - 1052	37
TSw1	1052 - 1797	37
Drill Hole Wash Fault	1901 - 1943	37
TSw2	1797 - 2720	37
Main Drift		
TSw2	2720 - 5500	37
Sundance Fault	3590 - 3630	37
South Ramp		
TSw2	5500 - 5729	37
TSw1	5729 - 6634	37
PTn	6634 - 6725	64
TCw	6725 - 6788	55
Dune Wash Fault	6787 - 6791	55
TSw1	6791 - 6990	55
PTn	6990 - 7058	55
TSw2	7058 - 7168	55
TSw1	7168 - 7440	55
PTn	7440 - 7514	82
TCw	7514 - 7603	109
TSw2	7603 - 7840	109
TSw1	7840 - 7877	182
South Portal	7877	182

The ECRB Cross Drift will be kept a minimum of 15 m to 20 m from potential WE zones within the primary WE area. Potential expansion areas (Bhattacharyya 1997; CRWMS M&O 1997h) that may be used as part of the potential repository lie beneath the Phase I section of the ECRB Cross Drift (0 – 476 m) east of the Ghost Dance fault. The closest potential WE zone under the Phase I section of the ECRB Cross Drift is assumed to be the contact between the upper lithophysal (Tptpul), and the middle nonlithophysal (Tptpmn) zones of the TS Formation, which constitutes the TSw1 - TSw2 contact (CRWMS M&O 1997h). This contact represents approximately the uppermost boundary of potential WE expansion areas beneath the Phase I section of the ECRB Cross Drift.

Table 9.2. Geologic and Hydrologic Features along the ECRB Cross Drift

Geologic/Hydrologic (G/H) Feature	Location of G/H Feature along ECRB Cross Drift (m)	Minimum Distance from G/H Feature to Potential WE Area[1] (m)
Phase I ECRB Cross Drift		
TSw1	0 - 773	~37
Drill Hole Wash faults	67 - 146	60
Ghost Dance fault	536 - 542	60
Phase II ECRB Cross Drift		
TSw1	773 - 1036	15 - 20
TSw2	1036 - 2540	15 - 20
Solitario Canyon fault splays	2540 - 2552	60
TSw1	2552 - 2674	62
TSw2	2674 - 2753	147
Solitario Canyon fault	2753 - 2758	221
TSw1	2758 - 2815	226

9.3 FRACTURE CONDITIONS

During excavation, a number of geologic faults and fault systems were encountered in the TS Loop of the ESF and ECRB Cross Drift (see above). The discussion below is summarized from Albin et al. (1997); Barr et al. (1996); Beason et al. (1996); and Eatman et al. 1997 and covers both these encountered conditions and the features of the GDF which, although not directly encountered in the Subsurface ESF excavations, is being studied from two exploration drifts excavated from the TS Main Drift eastward to the face of the GDF, and the Solitario Canyon fault which will be studied from the ECRB Cross Drift (and potentially associated auxiliary excavations).

9.3.1 Bow Ridge Fault

This north-striking fault occurs in a zone about 2.7 m thick within the ESF North Ramp about 200 m from the North Portal. This fault is a steeply westward dipping normal fault composed of three distinct breccia zones with about 100 m of Tertiary displacement, which brings the TSw1 in the upthrown foot wall into contact with the TCw/UO in the hanging wall.

9.3.2 Imbricate Fault System

This is a system of steeply dipping (generally westward) normal faults which strike north to northwest between 400 m and 2800 m from the North Portal. Eight faults occur between 400 and 1200 m and have between 4 and 18 m of offset. Fifty-nine minor faults occur between 400 and 2800 m and, in general, have less than 3 m of offset. These minor faults are believed to be the result of stresses associated with the cooling of the ash-flow units and not from tectonic activities (Barr et al. 1996).

[1] Note: Approximated by determining "straight-line" distance to closest waste package using a right triangle.

9.3.3 Drill Hole Wash Fault

The Drill Hole Wash Fault is comprised of two distinct faults encountered at 1901 m and 1943 m from the North Portal, with a strike of 316 and 150 degrees, respectively. Both faults dip steeply to the west. Approximately 4 m of normal movement (i.e., vertical offset) has been measured along this fault, with an indeterminate amount of associated lateral movement. The fault system is expected to be encountered during Phase I of the ECRB Cross Drift between 67 m and 146 m from the start of the ECRB Cross Drift.

9.3.4 Sundance Fault

This is the main structure occurring close to the center of the Sundance fault system that is a wide zone of northwest striking, nearly vertical, strike-slip faults. The Sundance fault was encountered in the TS Main Drift at 3590 m to 3630 m from the North Portal of the TS Loop excavation. Offset was not measured due to the numerous non-interconnected faults and shears that occur throughout the Sundance fault zone.

9.3.5 ESF Main Drift Fracture Zones

Over 10,100 fractures were encountered in the ESF Main Drift between Stations 28+00 m and 55+00 m, with only 7360 having lengths of 1 m or longer. Fractures are defined as cooling joints, vapor-phase parting entries and general fractures. Four "fracture sets" were identified with strike and dips of 120 degrees/82 degrees for set "1"; 220 degrees/83 degrees for set "2"; 310 degrees/22 degrees set "3"; 292 degrees/51 degrees for set "4." Additionally, four domains (e.g., fracture zones) were defined along the ESF Main Drift using azimuth-distribution histograms. Domain "1" occurs from Stations 28+00 m to 37+00 m; Domain "2" occurs from Stations 37+00 m to 42+00 m; Domain "3" occurs between Stations 42+00 m and 51+50 m; and Domain "4" occurs between Stations 51+50 m and 55+00 m.

9.3.6 ESF South Ramp Fractures

There are 710 features (faults and shears) that have been mapped along the south ramp area with less than 4 m of offset that occur between Stations 55+00 m and 78+77 m. Generally these minor faults are steeply dipping normal faults. Additionally, there are six faults that occur over the same interval along the south ramp that have greater than four meters of offset. Two of these features have greater than 50 m of offset including the Dune Wash Fault (Section 9.3.7). The remainder have less than 15 m of offset, including the GDF (Section 9.3.8). All of these faults are steeply dipping and have normal down to the west movement.

9.3.7 Dune Wash Fault

This is a steeply westward dipping normal fault intersecting the ESF Tunnel from Stations 67+87 m to 67+91 m with 52 m of vertical offset. The Dune Wash Fault is composed of two planes of clast supported breccia, with angular to subangular clasts of Tiva, Topopah, and bedded tuff ranging from 1 cm to 20 cm. The Tpcpln is exposed in the hanging wall and the Tptpul is exposed in the hanging wall. Both are highly fractured, with the fracture zones extending several meters out from the contact into the blocks.

9.3.8 Ghost Dance Fault

The GDF was encountered at Station 57+30 m and in Alcove #6. The GDF is a normal fault that crosses the TS Main Drift at Station 57+30 m is oriented at 205 degrees and has 1.2 m of offset downward to the west. The fault zone consists of a clast supported breccia with angular to subangular clasts of Tptpmn and Tptpll ranging from less than 0.5 cm to 15 cm. Both the hanging wall and the footwall are moderately to intensely fractured with the fracture zones extending away from the fault. The fault system is expected to be encountered during Phase I of the ECRB Cross Drift between 536 m to 542 m from the start of the ECRB Cross Drift.

9.3.9 Solitario Canyon Fault System

The Solitario Canyon fault system was not encountered during the TS Loop excavation of the ESF. Information concerning the Solitario Canyon fault and associated splays has been compiled by surface geologic mapping and trench studies. The Solitario Canyon fault system is generally a north-south trending westward dipping fault with associated splays. Greater than 10 m of offset is predicted for the main fault within Solitario Canyon. Two splays of the fault system are expected to be encountered during excavation of the ECRB Cross Drift between Stations 25+40 m and 25+52 m and between Stations 27+53 m and 27+58 m of the ECRB Cross Drift. This fault system will be encountered during the excavation of the Phase II section of the ECRB Cross Drift.

9.3.10 Fault Fracture Densities

Fracture densities are generally higher in the vicinity of these faults and fault systems. As such, these fault zones have potential to act as faster pathways for fluid flow, perhaps providing test access to the water table. Fracture densities expected for the hydrogeologic units discussed above are given in Montazer and Wilson 1984 as 10 to 20 fractures/m^3 for the TCw, 1 fracture/m^3 for the PTn, 8 to 40 fractures/m^3 for the TSw, and 2 to 3 fractures/m^3 for the CHn.

9.4 HYDROGEOLOGIC/GEOCHEMICAL CHARACTERISTICS

Beneath the TS Loop and ECRB Cross Drift excavation, the water table is relatively flat, with a slight gradient to the east, and lies primarily in the CHn hydrogeologic unit (Scott and Bonk 1984; YMP 1998a). The groundwater table lies in the TS Formation (TSw3) west of the Bow Ridge Fault and in the CHn unit east of the Bow Ridge Fault (Scott and Bonk 1984). The saturated groundwater flow in this area is inferred to be in a southeasterly direction, away from the conceptual repository (Ervin et al. 1993).

Water entering the TCw or TSw hydrogeologic units along the TS Loop and ECRB Cross Drift may result in water movement through fractures, matrix, or some combination of the two paths (Dunn and Sobolik 1993). The degree to which water movement in fractures is attenuated by capillary imbibition into the matrix is poorly understood at present. The PTn and UO (particularly the Timber Mountain Tuff portion) are believed to be relatively unfractured with matrix permeabilities that are high in comparison with the TCw or TSw matrix. Therefore, movement of water in these materials is believed to be dominated by matrix flow.

The Bow Ridge Fault zone has a displacement of about 100 m, which results in a discontinuity in the PTn across the fault (CRWMS M&O 1995b). This discontinuity may provide continuous fracture pathways for water movement across the PTn hydrogeologic unit to potential WE zones in the TSw2 hydrogeologic unit. Because of the offset on the Dune Wash Fault, a similar case occurs in this region where it may provide continuous fracture pathways for fluid movement across the postulated PTn capillary barrier to potential WE sites within the TSw2.

Although it is possible to identify qualitatively the potential impacts from perturbations to the geochemical characteristics of the Yucca Mountain site (e.g., dissolved organic carbon [DOC] may be a food source for microbes which may then cause changes in water chemistry that may enhance corrosion of the waste package or radionuclide solubility/transport), in many cases the data to quantify each causal link along the path to radionuclide release are not available. Because the quantitative data are not available for these relational links, it is not possible currently to evaluate the potential TFM impacts at the level of consequence to radionuclide releases. Therefore, we have adopted surrogate performance measures as the criteria for indicating that an item/activity may impact waste isolation.

In general, such surrogate criteria are based on the idea that potential *local* perturbations to ambient site conditions that are below the level of the natural system variability would be indistinguishable from the ambient system. For cases in which site data are not available to quantify the ambient system variations, the variability of aqueous geochemical parameters across the site is assumed to be *at least* 10 percent of ambient conditions. One example of such a surrogate criterion is the 10 percent increase in background aqueous nitrate concentrations used as the limit for local perturbations to the nitrogen system. This type of evaluation produces recommended limitations based on the *local* perturbations to the geochemistry at the *closest* waste package-if changes were expected across the entire conceptual repository, then these types of surrogate criteria would not be appropriate. As such, these evaluations produce recommended limits to keep *local* geochemical perturbations *within* the "noise" of the ambient geochemistry, with any farther-reaching changes kept commensurately smaller (this would not be applicable if the 10 percent change occurred over the entire site).

The average concentrations and standard deviation of measurements (Yang et al. 1988, 1990) for five constituents of UZ fluids are shown below in Table 9.3.

Table 9.3. UZ Dissolved Ion Concentrations: Sample Average, Sample Standard Deviation, and Percent Uncertainty.

Ion	Average Concentration* (ppm)	Sample Standard Deviation* (ppm)	Standard Deviation Percent of Average
$SO_4^{=}$	92	53	58
Cl^-	70	25	36
Ca^{2+}	60	30	50
Mg^{2+}	11	4.7	43
Na^+	45	15	33

* Values calculated from data given in Yang et al. (Yang et al. 1988, 1990).

Although data are limited for dissolved constituent concentrations in UZ water, the available data indicate that a 10 percent perturbation of the average ambient value is limited to about one third to one sixth of the actual sample standard deviation for the dissolved constituents shown above in Table 9.3. The assumption that using a 10 percent perturbation of the average ambient value is, in general, a *conservative* criterion for being within the noise of the natural system. In addition, as pointed out by Yang et al. (1988, 1990), the analytical uncertainties for values of the concentrations in the UZ waters are ±5 percent in general and ±10 percent for sulfate. Based on these data, the assumption that local perturbations to the ambient geochemistry of 10 percent or less cannot be differentiated from the natural system variation is very conservative.

10. IMPACT ON SITE CHARACTERIZATION TESTING

10.1 INTRODUCTION

The purpose of proposed subsurface excavation, utilities installation, and operations support is to facilitate underground testing. The ESF is an underground facility for conducting tests and collecting scientific and engineering data to be used for (1) assessing the suitability of the Yucca Mountain site for radioactive waste disposal, (2) providing design information for construction of the rest of the ESF and the potential repository, if the site is found to be suitable, and (3) the characterization of the site per Nuclear Regulatory Commission repository licensing requirements. Site characterization activities are planned throughout the ESF underground excavation areas. Most of the long-term testing activities are confined to test support areas constructed near selected geologic features (e.g., TTF, Ghost Dance Fault alcoves). Geologic and geochemical sampling, mapping, and geomechanical monitoring activities normally occur as soon as practicable after excavations have occurred. Design specifications and drawings describe facilities and components that are required for Science and Engineering Testing (S&ET) underground testing activities during the construction and operation phases.

The acquisition of scientific data through testing and monitoring activities requires close coordination between the constructor, design team, and scientific staff. This coordination responsibility lies with the S&ET TCO. Coordination of construction and Subsurface ESF testing resides with the TCO and the Site Services and Field Support Organization (SS&FS). Specification 01501 (CRWMS M&O 1999b) acknowledges that the ESF is a testing facility and that the SS&FS responds to the requests of the TCO which represents the site testing community. The SS&FS and TCO jointly derive working construction schedules that define: (1) sequencing of testing activities, (2) support required from the constructor for areas under construction, and (3) conduct of testing. Test specific construction support requests from the TCO are communicated to the SS&FS through QA approved (1) FWPs for each funded underground test activity or (2) documented field change interactions.

The TCO serves as the field coordinating agency for all test implementation, and represents the interests of the DOE, M&O, and PIs for all NEPO testing activities. The TCO maintains a presence at the ESF when construction and/or testing is occurring. Some instrumentation monitoring activities are performed remotely.

10.2 UNDERGROUND FACILITIES AND EXPERIMENTS

Underground facilities required to support testing operations are installed as underground construction proceeds, and as underground experiments are planned throughout the ESF. The test interference concerns associated with these activities are addressed in various other sections of this evaluation (CRWMS M&O 1998e).

The CH Formation, which lies stratigraphically below the TS unit, is considered a primary natural geochemical barrier against potential radionuclide migration from the repository. Various *in situ* site characterization tests have been proposed to further assess the CH unit, perhaps with access provided via a drift. Current minimization of water usage in the ESF is therefore important to preserving the *in situ* conditions in the underlying CH unit.

10.3 SATURATED ZONE TESTING

The ESF and the proposed repository block are approximately 337 m to 480 m above the water table. No test interference from subsurface testing is expected for the tests planned in the SZ because of this distance of separation.

10.4 EXISTING AND FUTURE SURFACE-BASED TESTS

Although existing construction of the TS Loop, ECRB Starter Tunnel, ECRB Cross Drift, associated support areas, and accompanying support systems is primarily a subsurface activity, some surface-based tests have the potential to be impacted. Surface-based tests that may potentially be impacted by any underground construction activities or associated support area construction are evaluated in the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). CRWMS M&O (1999a) specifically discusses the potential test interferences between Alcove #4 testing and NRG-4.

Surface-based drilling in the vicinity of the Subsurface ESF is planned during outyears. Test interference issues specific to the proximity of the proposed borehole location in relation to the ESF (repository block) will be addressed in evaluations (or equivalent documentation) prepared for those specific activities. Requirements to avoid these specific test interference issues will be addressed by the applicable FWP for the specific test.

10.5 UNDERGROUND CONSTRUCTION IN DIRECT SUPPORT OF ESF TESTING

Excavation activities occur concurrently with the installation and operation of required utilities and with support activities for underground testing operations. Drill-and-blast or mechanical excavation may be used to construct and access identified test support areas. Excavation effects on rock properties shall be taken into consideration when fielding tests along any underground opening and in the test support areas. In the following paragraphs, the potential test interferences associated with underground construction and test support area excavation methods and utilities systems are discussed.

10.5.1 Impact of Underground Excavation on Testing

Measurement and observation of air flow into and out of boreholes observed at Yucca Mountain indicate that there are diurnal, seasonal, frontal, and wind-driven barometric pressure differences between the atmosphere and the interior of the mountain. These pressure differences may induce circulation of air in the unsaturated, fractured rock. NEPO conducts testing activities to gain a more conclusive understanding of the role of present-day gaseous flow and pneumatic pathways in the UZ of Yucca Mountain to assist in the prediction of how such pathways could affect coupled heat, water, and gas flow systems after the potential repository is in operation. An evaluation of the thermal loading strategy is conducted to gain information on those regions where gas-phase convection processes dominate conduction as a potential heat transfer mechanism. Activities in the Subsurface ESF may disrupt the natural gaseous flow in its vicinity by creating a pneumatic pathway across the relatively impermeable PTn unit, and hence, effectively connect the more permeable welded units of the Tiva Canyon and TS members of the Paintbrush Tuff.

The potential of connectivity of pneumatic pathways across the PTn is addressed in the UZ testing and monitoring program conducted in underground and surface-based boreholes throughout the Yucca Mountain area. These data feed into a conceptual model of moisture and gas flow in the UZ. Some of the tests involve monitoring the barometric pressure changes that occur naturally and observing their effects at depths within the mountain. These tests are conducted in boreholes drilled from the surface and underground, which enables the scientists to correlate information on rock volumes of thousands of cubic meters (m^3). Such large-scale observations are important to the extrapolation of overall test information relevant to the scale of the mountain. Test interference issues are typically insignificant. However, during planning for each new test or phase of testing additional evaluation is performed. If there is a potential for test-to-test interference, controls are established and reflected in the field implementing documents.

The underground ESF ramps, drifts, niches, and alcoves represent major data gathering facilities for Yucca Mountain site evaluation activities. Test interference concerns with regard to testing in the CH geologic formation and surface-based tests are discussed above in Sections 10.2 and 10.4. Testing concerns with regard to the potential for operational spills and leaks are presented in Section 10.5.1.1 through 10.5.1.10.

Tests within the underground workings of the ESF will continue to be prioritized to develop and maintain an integrated construction and testing schedule. The following groups of tests have been identified and are currently in a test mode status (active or monitoring):

- Tests in the Upper Tiva Canyon Alcove (Alcove #1)
- Tests in the Bow Ridge Fault Alcove (Alcove #2)
- Tests in the Upper Paintbrush (non-welded) Contact Alcove (Alcove #3)
- Tests in the Lower Paintbrush (non-welded) Contact Alcove (Alcove #4)
- Tests in all locations situated within the TTF (Alcove #5)
- Tests in the Northern Ghost Dance Fault Alcove (NGDFA, Alcove #6)
- Tests in the SGDFA (Alcove #7)

- Tests in the TS Loop and niches
- Tests in the ECRB Cross Drift, niches, and alcoves

10.5.1.1 Tests within the Excavation Envelope

The testing that must occur within the active construction envelope is generally conducted as soon as possible after the applicable portion of excavation has been completed. Typically, these activities are not sensitive to continued mining operations, but provisions for adequate testing access may be required of the constructor to the extent that safety concerns are not impacted. However, if free or flowing (perched) water or other significant unexpected geologic conditions are encountered, the TCO could request that the CMD delay construction advance, if the initial assessment by the TCO is that this condition could be significant to on-going or planned testing (e.g., the collection of otherwise irretrievable data) or construction. Such a request would be reviewed by DOE for concurrence.

The following tests may be conducted within the active construction envelope during all phases of underground operations. The TCO will coordinate with the CMD to address access needs as well as test-to-test interference issues.

Perched-Water Testing in the ESF

Perched-water zones must be sampled and examined as soon as possible after they are encountered. An assessment is made by the TCO, as soon as practical, as to appropriate sampling methods. When perched-water is encountered (as indicated by free or flowing water), the TCO, in conjunction with the PI (or designee) and the CMD, determines whether to interrupt excavation operations to allow for more complete testing and sampling. Small perched-water zones may only require that samples be collected, along with an estimate of the flow rate and of the total volume of water produced, thus allowing construction to resume with minimal delay. Extended duration access may be required for long-term sampling and monitoring of any encountered perched-water zones, and could continue until: (1) the nature or origin of the perched-water body is determined and (2) all test-related quality-affecting activities are completed. (YMP 1997b)

Consolidated Sampling

Testing access is required for locations identified during geologic mapping for deferred sample collection. Some samples, such as gels, have to be collected as soon as practical after they are detected in a new exposure. Such sample collections must occur before installation of ground support and wall washing. No water or tracer, other than the traced construction water and air-misted water used for cleaning tunnel walls, should be used in the immediate vicinity of a sampling location without the approval of the PI via the TCO field contact. At the present time, LiBr is the only approved tracer to be used in construction and cleaning water for underground activities. The use of TFMs, especially in construction, in the proximity of the sampling location shall be documented. (YMP 2000b)

Construction Monitoring

Access is required to drill short, small-diameter boreholes and install instrumentation to determine the effects of construction on tunnel rock characteristics. No test interference impacts associated with construction monitoring activities have been identified. The use of TFMs, especially in construction, in the proximity of the sampling location shall be documented. (YMP 1999b)

Geologic Mapping Associated With Excavation Operations

Geologic mapping is an ESF site evaluation activity that may conflict with required ground support requirements. The ESF roof and walls require installation of rockbolts for stability. Where necessary, due to safety concerns, straps, ring beams, steel lagging, steel sets, wire mesh, interlocking wire mesh, shotcrete, or full concrete lining may be installed. Because geologic mapping is a photographic and observational activity, best performed as soon as possible following excavation, immediate installation of ground support could obscure geological details and is performed, to the extent practical, after geologic mapping has been completed. Thus, for normal mapping operations, it is preferred that nothing more than pattern bolting and, if necessary for safety concerns, approximately 15.2 cm or greater wire mesh be used. If additional ground control (such as steel sets, lagging, wire mesh less than 15.2 cm, or shotcrete) is required due to poor ground conditions, the TCO and the mapping PI confer with the CMD to identify if the needed ground support can be installed in a manner that allows the collection of geologic data to the extent practicable. (YMP 2000a)

Water used to clean the tunnel and alcove walls for geologic mapping has LiBr tracer added to it (expected range of 18 to 22 ppm). A minimum amount of water is used during blowdown cleaning and drilling operations to suppress dust. If compressed air is used in the cleaning operation, it does not require tracer. (Elkins 1993)

Moisture Studies in the ESF

These studies are conducted in any underground drift, alcove, or niche. Instrumentation in support of this activity may be placed outside of or into boreholes drilled for these studies or into boreholes not used for other testing activities. When alcoves or niches are constructed for this activity, temporary bulkheads may be constructed to isolate these areas from ventilation effects. These bulkheads may be constructed of steel and sealed with shotcrete, sodium silicate, or nonpermeable plastic cloth. (Peters 2000; YMP 2000c)

The moisture studies scope includes the controlled introduction of traced water onto the ground surface above Alcove #1 and the subsequent measurement of infiltrated water into the alcove approximately 30 m below. Similarly, monitoring for meteorological water infiltration into Alcove #7 is ongoing. No test interference has been identified between these water infiltration activities and other ESF activities.

10.5.1.2 Tests in the ESF Ramps, Drifts, Niches, and Alcoves

Alcoves and niches are typically located at faults or key geologic contacts. Of particular interest is the permeability of these faults and contacts and the role they play as pathways. Some of the instrumentation in these alcoves (1) collect data that would be irretrievable if construction were deferred until the entire test area was constructed, and/or (2) require installation as soon as possible to collect information significant to major milestone deliverables. These test areas are constructed as soon as practicable after: (1) the excavation operations have crossed the fault or contact; (2) specific testing and construction requirements are identified; or (3) design analyses, specifications, and/or drawings are modified (or created), as necessary, to address testing and construction requirements.

Grouted rockbolts must not be used in the test areas without TCO approval, due to the distances that grout may travel away from rockbolts installed in the fractured rock. This is a precaution to avoid altering gas samples and air permeability data by either altering the *in situ* rock gas chemistry or by filling fractures that provide pathways for gas flow (Sections 10.6.1.2 and 10.6.2 of CRWMS M&O 1999a). Split sets, other mechanical bolts, wire mesh, steel sets, or other materials (if approved in accordance with the TFM procedure [AP-2.17Q]) are acceptable for ground support. Before placing any shotcrete or other cementitious material in the alcoves for personnel safety, rock support, or other purposes, the field operator coordinates through the TCO to acquire PI concurrence and any special instructions for minimizing testing impacts.

Temporary bulkheads may be constructed at selected locations in alcoves, niches, and in the ECRB Cross Drift to isolate testing areas from ventilation effects. These bulkheads may be constructed of steel and sealed with shotcrete, sodium silicate, and/or nonpermeable plastic cloth, as appropriate. Personnel and equipment access will be controlled and limited while these bulkheads are in place. Ventilation of the isolated areas and access through these bulkheads will be coordinated between the CMD, TCO, and appropriate PIs such that there will be negligible test interference.

Per Neubauer (1999), the laser strain-monitoring device (Section 6.9.4) tubing, monuments, and instrumentation are of a robust enough design such that normal TS Loop construction traffic and operations are unlikely to affect the testing. Data will be collected remotely approximately once per day during low activities time to minimize the potential for construction-to-test interference. Furthermore, the brackets, monuments, and boreholes were located so as to minimize the potential for test-to-test interference with ongoing testing and monitoring activities in that section of the TS South Ramp. As such, no test interference concerns have been identified with this planned laser strain-monitoring activity.

Per CRWMS M&O 1999a, misted water sprays on the cutterhead of the mechanical excavator and water sprays on the conveyor of the excavator during excavation of ECRB auxiliary excavations (i.e., ECRB niches and alcoves) was permitted, but only in the access drift areas for the niches. Furthermore, spray head types and flow rates along with procedures for maintaining spray units were submitted to the Architect/Engineer (A/E) for approval before use in the access drifts. There will be no test interferences with planned testing provided these water sprays are restricted to the access drifts of the ECRB niches.

10.5.1.3 Tests in the Thermal Testing Facility

The location of the TTF is near the end of the North Ramp curve, in the TSw2 unit. The purpose of the TTF is to conduct TMHC *in situ* tests, which require a long time duration to obtain data. Test interference concerns regarding new construction should be the same controls established for all underground activities and should not have an impact on the TM tests to be conducted in this area. Additional test-specific controls may be included in revisions to FWPs for activities conducted in the TTF. Evaluations will be performed when new or additional testing requirements are identified. These new evaluations may invoke new or additional controls for testing. Post test characterization activities describe in Section 6 will be controlled by a FWP and are not expected to present any test interference concerns.

10.5.2 Hydrocarbons

Diesel-fueled equipment is used to remove broken rock from alcove and niche excavations (also see discussion in CRWMS M&O 1999a). Use of hydrocarbons, such as lubricants, engine oil, and coolants for this equipment must be controlled, to the extent practical, to prevent and mitigate releases to the subsurface environment. No test interference potential is expected from the use of operating fluids as long as they are not spilled or spills are cleaned up. Refueling, routine maintenance that involves lubricants, engine oil, or coolants, and repair should be performed carefully to minimize the potential for spills. Any spills must be reported in accordance with the TFM Procedure (AP-2.17Q).

10.5.3 Compressed Air Distribution

Provisions will be made in the applicable FWPs to prevent the introduction of condensed liquid water from the compressed air supply into tests that are sensitive to water, including all hydrologic tests. No other test interference concerns are expected since the accumulated oil and water from the air treatment process are not reused underground without additional processing and are disposed of in accordance with environmental regulations. Compressed air used in the conduct of experiments and testing for site characterization may be traced with a chemical tracer. Since this is not a construction-to-test interference requirement, but a potential prerequisite for specific site characterization testing activities, any tracing requirements are addressed by the applicable FWP for the specific test.

10.5.4 Fire Protection System

Release of fire suppressing agents (including water) should be treated as a large spill and dealt with accordingly. Fire suppressing dry chemicals proposed for the fire extinguishing system have been considered in terms of TFM parameters by this evaluation (Attachment II). Quantities of all materials used should be reported in accordance with the TFM Procedure (AP-2.17Q). If additional fire suppression agents are selected for use, their potential impact on site characterization activities must be evaluated in accordance with the TFM Procedure (AP-2.17Q).

10.5.5 Subsurface Conveyor System

The subsurface conveyor system employs operating fluids such as lubricating oils, hydraulic fluids, grease, dust suppression water, and other potential contaminants. The potential for leakage and spillage from causes including failure, damage, wear, repair, servicing, and accidents have been evaluated, and reasonable methods for precluding and mitigating the leakage and spillage of fluids have been incorporated in the system design. Accidental spills must be reported in accordance with the TFM Procedure (AP-2.17Q).

The subsurface conveyor system is equipped with a dust control and suppression system to contain the dust generated by the handling and conveying of muck. As part of this system, water spray headers are installed at each loading and transfer point. LiBr is added as a tracer to water used for dust control, and for other underground construction, except as exempted (Elkins 1994a). Water volumes used for dust control must be measured (e.g., totalizing flow meters) and records must be maintained and recorded routinely, identifying the quantities.

Generally, most of the water used for conveyor system dust control will be applied directly to the muck and so will also be carried out with the muck. The design is such that the amounts of water applied at each transfer point are minimized to avoid excessive water application that could result in spillage of water off the conveyor belt onto the tunnel invert. No construction-to-test or operation-to-test interference is anticipated as a result of this activity, assuming the identification, mitigation, and cleanup of spills. In addition, the amount of water applied is also monitored. Spills of muck should be avoided, to the extent practical, and cleaned up as soon as practical, when they do occur, to avoid and/or limit introduction of dust control water onto *in situ* rock.

10.5.6 Power Distribution System and Lighting

Generally, conveyor and ventilation system components are electrically grounded at intervals of approximately 300 m. Potential test interference exists if the ground enhancing material contains chloride. The ground enhancing material to be used should be one that is chloride-free, such as the coal-derivative GEM®.

Electrical equipment, transformers, cabling, communication systems, etc. installed underground have the potential to influence test equipment as a result of electromagnetic interference (EMI). It has been agreed by the TCO that during the development of each FWP (as applicable), the PIs responsible for the test will coordinate with the A/E to survey the specific site where test equipment is located (as necessary) and determine if additional electromagnetic protection is required. Due to this coordination effort, no test interference is expected to occur from installation and operation of the power distribution and lighting. The constructor may be required to install EMI shielding or other mitigation as part of the implementation of the FWP.

Uninterruptible power supply and emergency lighting systems may be used as long as spills (e.g., battery acid) are avoided. If spills occur, they must be cleaned up as soon as possible. The volumes and locations of any unrecovered spills must be documented and reported in accordance with the TFM Procedure (AP-2.17Q).

10.5.7 Subsurface Wastewater Handling System

No test interference due to the subsurface wastewater handling system is anticipated, provided: (1) components such as pumps and motors incorporate methods for minimizing potential for leakage, to the extent practical; and (2) leaks and spills are identified, mitigated, and reported in accordance with the TFM procedure (AP-2.17Q).

All sumps shall be lined with concrete or impermeable substance and a waterproof seal must be applied to prevent water from entering the rock mass. The sumps are expected to remain dry most of the time. Water collected in the sumps will be pumped to the surface. This minimizes potential test interference concerns regarding seepage into the rock mass of water collected in the sump.

10.5.8 Subsurface Ventilation System

Ventilation fans are located (subject to ground conditions, tunnel construction, and safety considerations) as required in the ESF. Sealed bearings on these fans reduce the potential for interference due to leakage of lubricating fluids. No interference due to the operation of the ventilation system is anticipated as long as: (1) leakage and spillage is avoided, to the extent practical, and (2) leaks and spills are cleaned up as soon as practical, in accordance with the TFM procedure (AP-2.17Q). Monitoring the ventilation system requires access to the entry and exit point for the exhaust ventilation line for periodic sampling or instrumentation. In addition, sampling ports are installed at selected locations along the vent line (Elkins 1994b). Access for these testing needs will be coordinated through the TCO via the applicable FWP.

The ventilation system circulates large volumes of atmospheric air through the Subsurface ESF, which will be at a slight negative pressure relative to the atmosphere. Under static barometric conditions, there is no advective flow of the tunnel air into the wall rock, and the only mixture with *in situ* gases is caused by diffusion. Under these conditions, the likelihood of test interference with hydrochemical tests of the gaseous system in the UZ is considered to be small and unavoidable due to personnel safety reasons. However, as atmospheric pressure increases (following passage of low-pressure fronts), the tunnel air, drawn from the outside atmosphere, may actually be at higher pressures than the gaseous pressures in the wall rock, which has not yet equilibrated to the increasing air pressure in the tunnel. Under these circumstances, there could be advective flow of the tunnel air into the wall rock.

The mixing of atmospheric air, which contains diesel combustion products, with the *in situ* gases constitutes a test interference in regard to radiocarbon age analyses of the UZ gases collected in the vicinity of the test area. Assessing the extent (i.e., distance) to which this impact will be detectable from the ESF opening is one application of hydrochemistry tests in the ESF. These data are used to resolve questions of geochemical sample representativeness; therefore, no test interference controls have been identified.

10.5.9 Subsurface Water Distribution System

The subsurface water distribution system supplies traced, non-potable water to the Subsurface ESF. Spill and leak control measures (e.g., isolation valves) were incorporated into the design to minimize or avoid test interference potential due to possible spills and/or leaks that could impact *in situ* rock moisture conditions and potentially bias nearby hydrologic tests. No test interference due to the operation of the underground water distribution system is anticipated as long as: (1) leakage and spillage is avoided, to the extent practical; and (2) leaks and spills are identified, mitigated, and cleaned up as soon as practical.

The Subsurface Water Distribution System also includes the tracer injection system. Because it would take simultaneous failure of the water delivery system and the tracer injection system, delivery of untraced water is not considered likely, therefore, no test interference impact is expected. If failure did occur, it would be treated as a spill and would be mitigated in accordance with the TFM procedure (AP-2.17Q).

10.5.10 Lining and Ground Support

Steel sets, lagging, concrete, grout, shotcrete, wire mesh, steel straps, and rockbolts are used for lining and ground support. Boreholes for rockbolts, anchor-bolts, and other ground support bolts are drilled into the tunnel walls utilizing electrohydraulic or pneumatic drills. Compressed air used for general construction drilling and construction does not contain a chemical tracer (Elkins 1994a). If water use is necessary, the amount of water must be kept to a minimum, and the water shall be traced.

Rockbolts may be cement grouted. Potential test interference exists due to possible alteration of the *in situ* pH of water/moisture in contact with the grout. Additionally, there may be potential for large volumes of grout to migrate significant distances away from the mined opening if it is emplaced under pressure. Cement grouting pressures and quantities must be limited, to the extent practical, including grout associated with rockbolt installation. The potential distances to which cement grout will penetrate into and through rock fractures and fault systems is directly related to the grouting pressures and grout quantities used. Accordingly, rockbolts must not be grouted in a test area, to the extent that safety concerns allow, without TCO approval. Because testing areas can be lengthened, as necessary, to further remove the testing location from grout injected along the mined opening, no additional controls have been identified.

Mixing water for concrete, grout, and pre-mixed (wet) shotcrete need not contain a chemical tracer (Elkins 1994a). Grout additives must not contain chloride, to the extent practical, to minimize the potential of affecting chlorine sensitive site characterization testing.

10.6 EXPERIMENTS AND OPERATIONS

10.6.1 Tracers, Fluids, and Materials

A large variety of TFMs are used for underground operations, installation and operation of utilities, and support of mining operations. All construction materials or substances used underground must first be reviewed for potential effects on engineered barriers, waste isolation, and on-site characterization or other testing. The TFM procedure (AP-2.17Q) adequately provides for this evaluation through the DIE process. The presence of combustible materials underground should be controlled and limited such that testing in the ESF is not adversely affected. Attachment II lists those TFMs that have been reviewed and approved for use by this evaluation. Attachment II also identifies special handling or storage requirements from a test interference perspective. Potential causes of test interference due to TFMs are discussed below.

Use of materials must be documented in detail and reported in accordance with the TFM Procedure (AP-2.17Q). Samples of TFMs used in alcove construction and testing construction are available for examination by NEPO PIs upon request.

10.6.1.1 Tracers

The addition of a universal tracer (LiBr is currently the selected tracer) is required for water used for underground dust suppression, wall cleaning before mapping, and other construction applications. LiBr is not required in water used in concrete, grout, or shotcrete mixtures, except when grout is required in the vicinity of perched-water testing as identified by the TCO. The concentration of LiBr tracer in the construction and mapping water should be within a range of 18 to 22 ppm.

Per Section 6, the use of LiBr tracers in significantly higher concentration has been requested in selected locations (i.e., niches, slot cuts, and Alcoves #1 and #8). These proposed uses have been coordinated with the PI(s) responsible for bromide-sensitive site evaluation testing by the TCO to minimize potential adverse impacts. Potential test interferences are taken into account by the responsible PI(s) when tests are fielded via integration of FWPs.

Compressed air used in blast hole drilling, short hydrochemistry boreholes, pneumatic tool use, and blowdown operations (before geologic mapping) does not require tracing with a chemical tracer (Elkins 1993). Compressed air used to drill core holes and for field experiments and testing in the test areas may be traced with a tracer, such as SF_6, if required by the PI(s). The predetermined tracer concentrations have been evaluated and impacts to other tests will be addressed. These and any additional tracer needs for ESF testing will be identified in the FWPs for the tests.

10.6.1.2 Water

Water is used for dust suppression during ESF operation. Additional water may be required for drilling operations, cleaning of the tunnel walls for geologic mapping, wetting down of muck piles in auxiliary excavations (e.g., alcoves and niches), and cutterheads on a roadheader or alpine miner. A chemical tracer should be added to this water to allow assessment of any effects on subsequent planned testing due to the addition of this water. The total volume of water used during ESF operations for dust suppression, alcove and niche construction, shotcrete make-up, blasthole and rockbolt drilling, and wall cleaning purposes to facilitate geologic mapping must be minimized, measured, and recorded. The TFM water records must list the types of applications associated with the water use. The Constructor will provide, at the request of a PI, samples for chemical analyses of all traced water used in the ESF.

10.6.1.3 Chloride-Based Materials

The use of chloride-based materials (e.g., sodium chloride, potassium chloride, magnesium chloride) must be limited, to the extent practicable, to minimize potential impact on chlorine-sensitive site evaluation testing. A non-chloride-based electrical grounding enhancement material must be used, and the use of chloride-based additives in concrete and grout must be avoided, to the extent practicable.

Per Section 6, the use of chloride-based tracers has been requested in selected locations (i.e., niches, slot cuts, and Alcoves #1 and #8). These proposed uses have been coordinated with the PI(s) responsible for chlorine-sensitive site evaluation testing by the TCO to minimize potential adverse impacts. Potential test interferences are taken into account by the responsible PI(s) when tests are fielded via integration of FWPs.

10.6.2 Materials/Objects Permanently Emplaced

Those items, not identified in the ESFDR (YMP 1997a) as permanent, shall be removed, to the extent practical. Those items identified as permanent (i.e., ground support) are not anticipated to cause test interference.

10.7 TESTING AT BUSTED BUTTE

The Busted Butte Facility lies to the southwest of the CCAB. The purpose of this testing activity is to study the CH geologic unit. Testing is conducted in the exposed CH unit located on the southern slope of Busted Butte. Testing activities are comprised of excavation and borehole studies as required to conduct a hydrologic transport test. Generally, controls established for previous ESF underground activities should be adequate to limit potential construction-to-test interference concerns. However, the planned tests are sensitive to water applications and certain TFM applications. Therefore, to limit the potential for construction-to-test interferences, approval of water applications and TFM usage is necessary. Should any new or additional testing requirements be identified, further evaluation will be required. The TCO must coordinate with the CMD to ensure that testing facility access requirements are satisfied and that potential construction-to-test and test-to-test interferences are minimized, to the extent practical. Drill-and-blast or mechanical excavation are acceptable methods for constructing the testing facility and accessing identified test support areas.

10.8 SUBSURFACE ESF TESTING INTERACTIONS

Testing sites are selected by the PI(s) in coordination with the TCO. The selection process takes into account potential interference from and with other test activities. As such, minimal test-to-test interferences associated with Subsurface ESF testing activities are anticipated. FWPs are developed by the TCO. FWPs ensure that potential interference from and with other test activities are minimized.

Although the Subsurface ESF provides the opportunity to test in more representative conditions than can be provided by surface outcrops, the tunnel opening itself introduces surface atmospheric conditions to a volume of rock where *in situ* data are desired. For example, an anticipated temporal lag between the time of tunnel excavation and when the tunnel effect may be transmitted into the rock mass is the window of opportunity in which certain planned ESF tests should be staged. In these cases, the deferral of testing until construction is complete could result in biasing the test results in an undetectable and unpredictable way.

Ideally, the goal of Subsurface ESF testing activities is to expedite (1) the completion of construction of the Subsurface ESF, as soon as practical, and (2) the acquisition of scientific data through testing and monitoring activities. Maximizing the potential of these goals requires close coordination between all affected organizations. The coordination between construction, and ESF testing and SBT resides with the CMD and TCO. The CMD and TCO jointly derive a working construction schedule that defines construction/test sequence for test support during the ESF excavation. Test specific construction support requests from the TCO are communicated to the CMD and implemented through FWPs.

11. IMPACT TO WASTE ISOLATION CHARACTERISTICS

In the sections below, the evaluations of potential hydrologic, geochemical, and TM perturbations which could lead to impacts to waste isolation are discussed. Analyses for the hydrologic perturbations due to water use and their potential impacts to waste isolation are presented. The evaluations of geochemical and TM perturbations and their potential impacts to waste isolation are based on the analyses in previous evaluations including: (1) DIE for the Subsurface ESF (CRWMS M&O 1999a); (2) TFM Usage and Excavation Methods for Use in Package 2C Exploratory Studies Facility Construction (CRWMS M&O 1995d); (3) DIE for Surface-Based Testing Activities (CRWMS M&O 2000b); and (4) DIE for the ESF Enhanced Characterization of the Repository Block Cross Drift (CRWMS M&O 2000a). In addition, the results of those previous analyses are generalized to consideration of testing activities within the entire ESF TS Loop and ECRB Cross Drift to derive controls that can be implemented throughout the TS Loop and ECRB Cross Drift.

In the specific geochemical evaluations discussed in Section 11.3, the conclusions were based on scenarios that should conservatively bound potential perturbations to ambient conditions. If such conservative calculations indicate that the items/activities are not likely to impact the ambient conditions above the level of the chosen surrogate criterion (as discussed above in Section 9.4), then it can be concluded reasonably that the items/activities can be used/performed with negligible risk for potential impact to waste isolation from any reasonable scenario (with only those controls that are applied in this evaluation). Because the specific evaluations discussed in Section 11.3 are conservative bounding scenarios based on surrogate criteria, it *cannot* be concluded that impacts to waste isolation are assured for cases where results *exceed* the surrogate criterion for negligible perturbations to ambient conditions. However, it can be reasonably assumed that the potential impacts to the surrogate performance parameters resulting from the geochemical changes in these scenarios represent upper bounds for impact for any plausible scenario.

To provide a consistent approach to evaluating the potential impacts in all cases, an effort is made to choose a *reasonable* bounding scenario. The bounding scenario is not taken from a subjective consideration of the "most probable" case, nor is it assigned from identification of the "worst case." In many cases, the "most probable" scenario cannot be identified quantitatively because lack of appropriate information precludes quantifying such probabilities. In addition, uncertainties in identification of the "worst case," and quantification of resulting effects, preclude using the "worst case" to constrain these evaluations in most cases. The bounding case is chosen, in part, because it can be quantified in a straightforward manner and includes conservative assumptions to ensure that it encompasses the potential impacts from virtually all reasonable scenarios. In all cases, it will be necessary for a future evaluation of the consequences to waste isolation resulting from the committed items and actual configuration of any final constructed facility.

11.1 HYDROLOGIC EVALUATIONS

11.1.1 Potential Performance Effects for a High-Level Nuclear Waste Repository at Yucca Mountain

The performance of a conceptual nuclear waste repository at Yucca Mountain is based on the strategy of waste containment, isolation, and attenuated exposure. Containment refers to keeping the waste inside waste packages, for example steel canisters, while isolation refers more generally to keeping the waste from reaching the accessible environment. Attenuation of exposure is a result of delay in the release and transport of radionuclides to the accessible environment and dilution of the radionuclides in the water. The accessible environment is where the public is potentially exposed to the waste. These three elements of the nuclear waste disposal strategy, containment, isolation, and attenuated exposure, are intimately related to the occurrence and behavior of water in the subsurface environment. Containment of waste is affected by water through the role water plays in corrosion and failure of waste packages, dissolution of radionuclides, and migration of dissolved radionuclides from inside waste packages to the surrounding geologic environment. The principal avenue for migration of the radionuclides from the rock at the potential repository to the accessible environment is by advective transport in water. Similarly, the travel times for radionuclides to reach the accessible environment are affected by advective transport in water. Finally, the dilution of released radionuclides that reach the accessible environment depends on the flow and mixing of water.

11.1.2 ECRB Cross Drift Water Loss

11.1.2.1 Phase II ECRB Cross Drift

Calculations of the changes in UZ flow below the ECRB Cross Drift, due to the introduction of construction water, does not, in itself, reveal if those changes are important to potential repository performance. The present total system performance model would require modifications to capture the effects of perturbing a small, discrete, portion of the UZ on bottom-line performance criteria such as dose or cumulative release to the accessible environment. However, we may argue more simply that if a small portion of the UZ flow field (i.e., the zone below the ECRB Cross Drift) is perturbed (after a specified minimum time) to some level less than the (estimated) natural variation in percolation flux across the potential repository block, then the effects of that perturbation on performance are negligible. Clearly, some minimum offset in time is required because at the time of emplacement the construction water may significantly alter the local UZ flow. However, because the application of construction water is short in duration, the effects of such an introduction of water are expected to diminish with time. The time offset picked, 300 years, is based on the 10 CFR 60 requirement for substantially complete containment of radioactive waste by the waste package for no less than 300 years. Therefore, the changes in the unsaturated flow system 300 years after introduction of construction water, relative to the estimated natural variability in percolation flux were evaluated in the ECRB Cross Drift DIE (CRWMS M&O 2000a).

The drainage time for the introduction of 0.5 m of water, such that the flux at the water table is within 150 percent of the undisturbed condition, is found to be about 300 years. For a transient flow model (Unsaturated Transient Flow Model), qualitatively, the response to 0.5 m of construction water is similar. Therefore, water loss per square meter (m^2) of ECRB Cross Drift floor area is limited to 0.5 m^3 over the lifetime of Phase II of the ECRB Cross Drift. This 0.5 m water limit is converted into a volumetric water loss limit per m of ECRB Cross Drift advance as follows: (0.5 m column of water x 5 m drift width x 1 m of depth ECRB Cross Drift advance)/1 m of ECRB Cross Drift advance = 2.5 cubic meters per meter (m^3/m) of ECRB Cross Drift advance (or approximately 660 gallons per meter [gal/m]). For excavations having a variable cross-sectional dimension, the limit for water loss (in m^3/m of excavation length) may be calculated from the product of 0.5 and the applicable cross-sectional dimension (in m).

11.1.2.2 Phase I ECRB Cross Drift

The effects of water on the near-field are conservatively restricted to a 5-m wide enhanced saturation zone, with the exception of the final 13 m of Alcove #8 where a 6-m wide zone is authorized. The use of a 5-m wide zone is a nominal, but conservative, width of the enhanced saturation region corresponding to the diameter of the ECRB Cross Drift excavation. This is conservative because smaller quantities of water will have a larger effect on saturation if restricted to this zone rather than more widespread dispersal in the geologic environment. Discharged water may propagate from its discharge point in the ECRB Cross Drift to the nearest potential WE zones. The tunnel diameter is used as the length scale appropriate to the introduction of water discharged in the tunnel to the geologic environment.

The limiting quantity of added water in the ECRB Cross Drift is assumed to be the amount required to saturate the rock lying between the nearest potential WE location and the ECRB Cross Drift excavation (CRWMS M&O 2000a). This quantity of water lost per unit length of excavation, QL, is $(1\text{-SI})*\phi*W*D_o$, where SI is the initial (undisturbed) water saturation, ϕ is the porosity, D_o is the minimum offset between the ECRB Cross Drift excavation and potential WE locations, and W is the width of the enhanced saturated zone. Given W=5 m (see Section 6.2 of CRWMS M&O 2000a), $\phi = 0.13$, $S_I = 0.74$ (CRWMS M&O 1996d, p. 13), and $D_o = 37$ m (Section 9.2), the limiting quantity of water discharged per unit length $Q_L = 6.25$ m^3/m or about 1650 gal/m. CRWMS M&O (2000a) applied the 6.25 m^3/m of ECRB Cross Drift advance (or approximately 1650 gal/m) as the Phase I water loss limit (ECRB Cross Drift Station 0+26 to Station 7+73 m).

11.1.3 TS Loop Water Loss

The effects of TS Loop water on the near-field are conservatively assumed to be restricted to a 7.62 m (nominally 25 feet) wide enhanced saturation zone. The use of a 7.62 m wide zone is a nominal, but conservative, width of the enhanced saturation region corresponding to the diameter of the ESF Main Drift excavation. This is conservative because smaller quantities of water will have a larger effect on saturation if restricted to this zone rather than more widespread dispersal in the geologic environment. Discharged water may propagate from its discharge point in the TS Loop to the nearest potential WE zones. The tunnel diameter is used as the length scale appropriate to the introduction of water discharged in the TS Main Drift to the geologic environment.

The analysis of the natural variations in ambient diffusive transport compared with average diffusive transport behavior under elevated water saturations is given in Attachment V of CRWMS M&O (1999a). The results of this analysis indicate that diffusive transport is not sensitive, relative to natural variations in diffusive transport at ambient conditions, to increases in water saturation from the average ambient water saturation to saturated conditions. A similar analysis for advective transport is presented in Attachment VI of CRWMS M&O (1999a). This analysis finds that advective transport is not sensitive, relative to natural variations in advective transport at ambient conditions, to an increase of water saturation from the average ambient water saturation to an average water saturation of 0.99, but marginally sensitive to saturated conditions. Because the transport process will disperse the saturation levels due to added water, the limiting quantity of added water in the ESF is assumed to be the amount required to saturate the rock lying between the nearest potential WE location and the ESF Main Drift and alcoves. This quantity of water lost per unit length of excavation, Q_L, is $(1-S_i)*\phi*W*D_o$, where S_i is the initial (undisturbed) water saturation, ϕ is the porosity, D_o is the minimum offset between the TS Loop excavations and potential WE locations, and W is the width of the SZ. Given W=7.62 m (Section 6.2 of CRWMS M&O 1999a), ϕ=0.13, and S_i=0.74 (CRWMS M&O 1996d, p. 13), and D_o=37 m (Section 9.2), the limiting quantity of water discharged per unit length Q_L=9.5 m^3/m.

11.1.4 Thermal Testing Facility/Heated Drift

Drilling of boreholes for test equipment in the TTF Heated Drift is planned to be performed using traced water as a circulating fluid to remove cuttings from the holes, as described in detail in Section 6.11. This process will result in the loss of a portion of the water used due to flow into the surrounding rock. The dense distribution and relatively large depth of boreholes (as compared, for example, with drilling rockbolt holes) requires a specific assessment to determine if this activity may have adverse effects on potential repository performance. The conceptual approach used here is to consider the entire borehole drilling pattern area (in plan view, shown in YMP [1997d]) as the area disturbed by "excavation." Given this conceptual approach, the total water use may then be derived from the existing water-loss limit for the TS Loop (Requirement 7 of CRWMS M&O 1999a) expressed on an equivalent per-unit-area basis. CRWMS M&O (1999a) states that water loss should not exceed 7.4 m^3 of water per meter of linear advance in the Main Drift and ramps to ensure a negligible effect on potential repository performance. These excavations have an effective width of 7.6 m (i.e., projected maximum horizontal width). The water loss limit is adjusted for excavations of different effective width by scaling the value of 7.4 m^3 (of water) per meter of excavation in proportion to the effective width of the excavation (see subparagraph *e* in Requirement 7 of CRWMS M&O 1999a). For example, a five-meter wide alcove excavation would have a water loss limit of:

$$[7.4\,\frac{m^3\,(of\ water\ loss)}{m\,(linear\ advance)}]*[\frac{5.0\,m\,(alcove\ width)}{7.6\,m\,(main\ drift\ width)}]=4.9\,\frac{m^3\,(of\ water\ loss)}{m\,(linear\ advance)}$$

This scaling rule is equivalent to limiting water loss in proportion to the plan-view area of the excavation. Expressed on a per-unit-area basis, the water loss limit is 0.97 m^3 of water per m^2 of plan-view area.

The model described above, which identifies a limiting water loss or consumption limit of 0.97 m^3 of water per m^2 of plan-view area, is based on an offset between site characterization excavations and the nearest potential waste package emplacement location of 37 m (CRWMS M&O 1995d). This distance is the minimum offset for any site characterization excavation. However, the TTF Heated Drift has been identified as being a minimum of 114 m (Section 6.11.4) from any potential waste package emplacement location. Using an offset distance of 114 m, then the model calculations for limiting water consumption and mobilization may be proportionally scaled to approximately 3 m^3 of water per m^2 of plan view area. This simple scaling is possible because the model results are directly proportional to the offset distance (CRWMS M&O 1995d). The amount of water per unit area that may be mobilized in the heated drift test may be derived from the estimated vertical thickness of the dry-out zone within the Tptpln lithologic unit. This thickness is estimated to be less than 24 m (CRWMS M&O 1996b). (It should be recognized, however, that the definition of the dry-out zone is that the saturation falls to a level below ambient. Therefore the amount of water mobilized will be less than the total amount of *in situ* water in the dry-out zone.) Using a porosity of 0.13 and a saturation of 0.74 for the Tptpln lithologic unit (CRWMS M&O 1996d), the maximum quantity of water mobilized in the thermal test is about 2.3 m^3 of water per m^2 of the heated zone. This leaves approximately 0.7 m^3 of water per m^2 of the heated zone for wet drilling of the non-vertical boreholes in the test bed adjacent to the Heated Drift.

Water use for construction within the Heated Drift may be divided among drilling of vertical boreholes, concrete, and excavation. Accounting for the excavated water, the maximum quantity of mobilized water in the rock volume including the Heated Drift (and using a 5-m diameter drift, see Section 6.11.4) is about 1.9 m^3 of water per m^2 of the plan-view area. Therefore, the amount of water available for construction is 1.1 m^3 of water per m^2 of the Heated Drift plan-view area.

The plan-view area for the borehole drilling pattern, shown in YMP (1997d), is approximately 1560 m^2. (Note: This area excludes the footprint of the Heated Drift itself. Water loss within the actual Heated Drift footprint--which includes the water lost during the excavation of the

Heated Drift and water lost during the drilling of the <u>vertical</u>[2] test boreholes that emanate from the Heated Drift--is treated separately, as noted below.) Therefore, the maximum total water loss for borehole drilling through this area is $(0.7\ m^3/m^2)(1560\ m^2) \approx 1090\ m^3$ of water, or about 290,000 gallons. The Heated Drift has an area of at least $47.5\ m \times 5\ m \approx 237\ m^2$ (CRWMS M&O 1997c). Therefore, for the Heated Drift, the maximum total water loss is $(1.1\ m^3/m^2)(237\ m^2) \approx 260\ m^3$ of water, or about 70,000 gallons. The total water loss limit for construction and testing in the Heated Drift and adjacent test bed for borehole drilling is 360,000 gallons distributed over a total plan-view area of about 1800 m^2, or about 200 gallons per m^2.

The implementation of restrictions on water use requires an infiltration area appropriate for averaging the specified limits. For the ESF, an averaging area of 76.2 m^2 was identified (CRWMS M&O 1999a), assuming a 37 m offset between the excavation and potential WE locations. This was based on the width of the excavation, 7.62 m over 10-m-long sections. The appropriate area in this case may be scaled linearly with the offset between the Heated Drift and the nearest potential WE location, which is 114 m (Section 6.11.4). Therefore, the appropriate averaging area is about 230 m^2. The total width of the alcove and test bed is about 38 m (CRWMS M&O 1997c; YMP 1997d). An appropriate averaging zone is a plan view-area which is about 38 m wide (transverse to the axis of the Heated Drift) and 6 m long (along the axis of the Heated Drift). Given a limiting discharge rate of 200 gallons per m^2 (as calculated above), the total quantity of water that may be discharged in an area of 230 m^2 is about 46,000 gallons.

11.1.5 Alcove #8/Niche #3 Testing

Tracer testing between Alcove #8 and Niche #3 has been specifically limited to 150,000 gal for the ongoing infiltration testing. This limit exceeds the initial established limit on water loss for Alcove 8 that was defined by ECRB water loss requirements (CRWMS M&O 2000a). This is based on a Pre-Test Modeling Evaluation performed by Lawrence Berkeley National Laboratory (BSC 2001). As described in the evaluation, the Alcove #8/Niche #3 cross-over test will be conducted at two locations (corresponding to fault testing and large infiltration plot testing, respectively) in Alcove #8 using the same test procedure at each location. The evaluation results should also be valid for the large infiltration plot test. The initial condition for modeling the test is the ambient condition corresponding to the steady-state flow field for the given percolation fluxes at the top boundary. The percolation flux value was approximated by the net-infiltration rate (5.07 mm/yr) at the top of the bed rock above the alcove (DTN: GS000399991221.002). The free-drainage condition was used as the bottom boundary condition. For this modeling study a 2 cm pressure head was assumed for the duration of the test period. After one year of test injection (Model assumption), the top boundary condition is assumed to be the ambient flow condition.

[2] For the purposes of this DIE, a test borehole is "vertical" if it is planned to be drilled vertically upward or downward as indicated by either the word "UP" or the word "DOWN" in the "Direction" column (the ninth column of the Administrative Borehole Layout Table in CRWMS M&O 1996b). That is, boreholes that are planned to be drilled vertically but that, in reality, may be drilled slightly askew from precisely vertical are considered vertical boreholes for the purposes of this DIE.

Alcove #1 testing demonstrated that the dispersion process in fractures has an insignificant effect on tracer transport behavior. The Alcove #8 Model assumes fluid dispersion is dominated by fracture flow versus matrix flow (based on Alcove #1 studies). In addition, low water flow velocity in the matrix allows the mechanical dispersion to be ignored. Results of operating the model over a 10,000 year period under conservative conditions indicate that the tracer plume is limited to about 20 meters away from the infiltration plot in the horizontal direction. Furthermore, the tracer plume should be washed out of the potential repository within the 10,000 years in the vertical direction (i.e., down). As such, a site-specific water loss limit has been established for the Alcove #8/Niche #3 testing. (Requirement 3c)

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11.1.6 Gaseous Radionuclide Transport in the Unsaturated Zone

The addition of water will affect gaseous radionuclide transport in the UZ. An increase in water saturation will always reduce the diffusive transport rate in the gas phase (Marshall and Holmes 1979, p. 271), or increase the diffusive travel times of gaseous radionuclides. Therefore, the addition of water is not expected to adversely affect potential repository performance.

11.1.7 Alcove #10

The amount of allowable water loss for Alcove #10 construction and testing is derived in accordance with Section 11.1.2.1 using the Requirement (5e) equation in CRWMS M&O 2000a. The following calculations identify the maximum water loss limits for construction and testing:

Planned excavation depth for Alcove 10 is 49 m which yields:
49 m x 2.5 m^2 = 122.5 m^3 (approximately 32,340 gal) which is the maximum water loss allowable for construction of Alcove #10.

Planned testing will occur in an in-situ block measuring 14 m by 7 m. with release of injected water into this block. This block will be located beyond the end of Alcove #10. Maximum water loss limits for this testing of the injection block is:

14 m x (7m/ 5m) 2.5 m^2 = 49 m^3 (approximately 12,940 gal)(49,042.6 liters)
As such no new QA controls are required.

11.1.8 Geotechnical Rock Properties Testing

Water use, in association with construction of these cored boreholes and the slot cuts (which are cut off the main drifts using a rock saw), will be kept within the maximum water loss limits for the TS Loop (every 20 m segment), and the ECRB (every 10 m segment) (Weaver 2001b).

11.2 TRACERS, FLUIDS, AND MATERIALS

The following discussion of potentially retained constituents from various fluids and materials was taken from the Subsurface ESF DIE (CRWMS M&O 1999a) for the ESF testing activities because of the similarity of substances to be considered for the entire TS Loop and from the ECRB Cross Drift DIE (CRWMS M&O 2000a) for the ECRB testing activities. Additional discussion and detailed references can be found in the corresponding sections of those documents. Tracers are viewed entirely as retained substances and so are not discussed further here but are evaluated below in Section 11.3. The specific TFMs listed in Attachment II have been reviewed to ensure that they all fall into the groups defined below and are therefore covered by any applicable controls.

The only items that are planned to be incorporated into the potential repository (i.e., planned *permanent* items) are (YMP 1998a, pp. 1-2): (1) underground openings; (2) ramp and shaft linings; (3) ground support; and (4) operational seals. Items which are left (intentionally or unintentionally) at the site *post-closure* (above and below ground) are defined as *committed* items in an evaluation of surface-based fluids and materials usage (CRWMS M&O 1994b). *Non-committed* substances are only those fluids and materials that are not being emplaced into the environment in such a way as to become a committed part of that environment. Such non-committed substances are those that are planned to be removed from the site at or before the time of closure, *and* are not expected to leave behind noticeable, non-removable residues. Certain materials may only be partially committed (i.e., penetration into the rock matrix of a few mm or cm) and if removed by chipping, overcoring, or similar activity can be considered non-committed substances (e.g., filler foams, epoxies, adhesives). Because of the condition of removal before closure, some solid materials are excluded from this evaluation designation of non-committed (e.g., salt) because they are soluble to the extent that they have the potential to dissolve into the environment over a relatively short time period (i.e., days to a few months). Based on the reasoning given in the evaluations of the Package 1A TFMs (CRWMS M&O 1994c), the surface-based non-committed fluids and materials (CRWMS M&O 1994b), and the Package 2C TFM (CRWMS M&O 1995d), non-committed items are assumed to have negligible impact on waste isolation and are not further evaluated.

Substances considered committed items and evaluated here for the TS Loop, testing alcoves, and the ECRB Cross Drift are: steel sets, lagging (wood and steel), wood blocking, lubricating oil retained (from cutting) on steel sets, rockbolts, wire mesh, sodium silicate, shotcrete and/or fibercrete, cementitious grout, oil mist from compressed-air system, steel, concrete, concrete admixtures, and galvanized steel. In addition, because diesel equipment will be employed during construction of testing alcoves and niches, and some of the exhaust constituents (both inorganic and organic) may become committed to the underground, the potential impacts of these constituents were explicitly analyzed in the Package 2C evaluation (CRWMS M&O 1995d) and controls on the quantities of materials committed are discussed in the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). Furthermore, in the event of a fire, combustion products and fire-suppression substances may become committed items. Therefore, the potential impacts to waste isolation from the proposed fire-suppression substances were also explicitly evaluated using a bounding scenario in the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). In the event of an actual fire, the specific materials that burn should be evaluated for potential impacts to waste isolation. Because fire products are not planned to be incorporated into a potential repository, a more general waste isolation evaluation should be performed if there is a need to further evaluate such potential impacts.

As discussed in detail in the Package 2C evaluation (CRWMS M&O 1995d), explosives are not considered committed items because it is assumed that most of their residues will be removed either as volatiles or within the excavated materials. The exception to this judgement is in the blasting used for active seismic mapping discussed in Section 6.7. The sampling of these boreholes will be required to determine the amount of residues remaining in the ESF. Based on these samples (or estimates) and further evaluation, overcoring of these active seismic mapping boreholes may be required before repository operations.

It was concluded in the Package 2C evaluation (CRWMS M&O 1995d) that fluids which are not planned to be dispersed into the environment (e.g., diesel fuel, lubricants, coolants, battery acid, cleaning solvents) are expected to have negligible impact provided that a plan for spill containment and clean-up exists. In accordance with the YMP procedures for recording TFM use at the site (AP-2.17Q), any planned non-committed fluids or materials that become retained intentionally or unintentionally as part of the committed environment require *documentation* of the amounts of substance retained in the environment and *evaluation* of the potential waste isolation impacts of that specific retention. The evaluation of specific materials that become part of the committed environment will be part of future TSPA evaluations.

11.3 GEOCHEMICAL EVALUATIONS

11.3.1 Tracers

As discussed in CRWMS M&O (1994c, 1995d), LiBr, proposed as a tracer for construction water, water for geologic mapping, and wet drilling of testing boreholes, will be added at a maximum concentration of 30 ppm (minimum 10 ppm), with a target concentration of 20 ppm (±2 ppm). In addition, SF_6 will be added at concentrations not to exceed 20 ppm to air used for drilling test boreholes. It was concluded in both of these previous evaluations that because of the low concentrations and limited quantities used, these tracers are expected to have only negligible effects on the geochemistry near potential WE sites, or along potential gaseous and aqueous radionuclide pathways.

SUVA-COLD MP® (tetra fluoroethane) has been evaluated for use in conducting tracer tests to estimate the tortuosity and effective porosity of faults and their associated fault zones. Given a borehole radius of 2 inches, the total volume of gas per 20 m segment is 0.162 m^3 ($V=\pi r^2 h$). The molecular volume of an ideal gas at standard pressure and temperature (V_m) is 0.0224414 m^3/mole; thus, the total number of gas moles per 20 m segment is equal to 7.2188. With the concentration of this gaseous organic tracer not exceeding more than 30 ppm (identified as the maximum State-approved concentrations in YMP 1996a; 1996b), the total number of moles of tetra fluoroethane is equal to 2.1656×10^{-4} moles. Because of the low quantities used, these tracers are not expected to have significant effects on the geochemistry near potential WE sites, nor along potential gaseous and aqueous radionuclide pathways if used within the TS Loop, ECRB Cross Drift, and associated auxiliary excavations.

In addition, Nitrogen and Noble Gases (i.e., Helium, Neon, Argon, Krypton, and Xenon), have been proposed for use as tracer gases to support ESF subsurface testing activities. These gases have a lesser potential to cause waste isolation effects than either SF_6 or tetra fluoroethane due to their extremely stable chemical state. The evaluation of SF_6 as a tracer gas is conservatively considered to be a bounding evaluation for the use of Nitrogen and Noble Gases as tracer gases within the Subsurface ESF. Therefore, these tracers are expected to have negligible effects on the geochemistry near potential WE areas, or along aqueous or gaseous radionuclide pathways.

11.3.2 Inorganic Substances

Items such as steel sets, rebar, lagging (steel), rockbolts, wire mesh, shotcrete and/or fibercrete, cementitious grout, and galvanized steel are expected to have negligible impact on waste isolation resulting from perturbations to the near-field geochemistry because their use near potential WE sites (i.e., within potential repository drifts) is expected to overshadow any effects resulting from their use in the TS Loop and ECRB Cross Drift.

11.3.3 Committed Organic Substances

Because of the numerous qualitative issues regarding committed organic materials (e.g., dissolved organic enhanced solubility and transport of radionuclides, and microbial effects), use of such materials in potential repository drifts is unknown. Therefore, the above reasoning on committed inorganic substances does not apply to any organic materials which might be contained within cementitious materials as a result of the addition of admixtures.

As pointed out in the Package 2C evaluation, organic compounds may accelerate waste package corrosion through enhanced microbial activity and/or facilitate radionuclide transport in the geosphere via complexing of cations (CRWMS M&O 1995d). This previous evaluation indicated these effects are constrained by the ability of deposited organic materials to migrate to either waste package locations or radionuclide pathways in sufficient concentration to have a significant impact.

The total organic budget includes all sources of committed organics in the Subsurface ESF. Examples of such sources are wood blocking/lagging for steel sets, oil mist from the compressed air system, lubricating oil (for cutting) retained on steel sets, organic diesel exhaust components, and concrete admixtures used in shotcrete. In addition to these introduced sources of organics, opening the mountain to the external environment allows the introduction of potentially committed organic materials in the form of airborne particles in the ventilation air and in the form of organisms that may inhabit, and deposit organic residue in, portions of the tunnel.

Accidental loss of any organic fluid such as fuels, lubricants, or coolants used in equipment necessitates documentation and evaluation of the specific unintentional releases, and incorporation of the retained amounts of committed organic fluids into the evaluation of the final configuration of the potential repository.

11.3.4 Fluorinated Organics, Fluorine Salts, and Non-Fluorine, Halogenated Salts

Due to numerous qualitative issues concerning the presence of Fluorine (F^-) and related complexes (e.g., hydrofluoric acid [HF]) at or near potential WE areas (e.g., enhanced degradation of spent fuel cladding material and/or waste package materials) use of such materials has been previously restricted to only gaseous compounds. Since Fluorine is naturally occurring in the repository horizon and can be measured at a quantifiable level, we may use the same rationale as that applied to dissolved organics in Section 11.3.3. Similarly, for other halogen-bearing salts. It is recommended that the use of these elements and compounds be limited to the quantities identified below to avoid potential waste isolation effects.

11.3.5 Committed Substances in the ECRB Cross Drift Phase II

The analysis given in CRWMS M&O (1995d) for committed TFMs is based on advective-dispersive transport from the discharge location to the nearest potential WE Drift (assuming instantaneous and complete dissolution of the organic-bearing, nitrogen-bearing, or sulfur-bearing compound). Other assumptions include matrix-only transport and a saturated matrix. The source configuration for an offset of 37 m (as for segment 4 of the North Ramp) or for the 15 m offset expected in the ECRB Cross Drift is assumed to act as an "infinite plane," with the source density determined by the source mass discharge per unit length of tunnel spread over the surface area of the drift.

We recap here the relevant portions of the analysis from CRWMS M&O (1995d). The infinite plane source allows the calculation of the concentration at the nearest WE Drift using the following expression (Equation 11-1) for one-dimensional advective-dispersive transport (Bear 1988),

$$C(x,t;m,\phi,v,D_x)=\left[\frac{m}{\phi(4\pi D_x t)^{1/2}}\right]\exp\left\{-\frac{(x-vt)^2}{4D_x t}\right\} \qquad \text{(Eq. 11-1)}$$

where m is the areal source mass density (in mass per unit area), D_x is the longitudinal dispersion coefficient, t is the time, x is the position, v is the flow velocity, and ϕ is the rock matrix porosity. Note that the dispersion coefficient is given by Equation 11-2 (Bear 1988),

$$D_x = a_x v = 0.1xv \qquad \text{(Eq. 11-2)}$$

where the scale dependence of the dispersivity, a_x, is taken to be one tenth of the distance traveled (de Marsily 1986). Substituting this expression for D_x and noting that $vt = x$ at the peak concentration leads to the following expression (Equation 11-3) for the peak concentration C_p,

$$C_p(x;m,\phi)=\frac{m}{\phi x(0.4\pi)^{1/2}} \qquad \text{(Eq. 11-3)}$$

which is linear in x. Also note that m may be expressed as Equation 11-4,

$$m = \frac{m_l}{\pi d_t} \qquad \text{(Eq. 11-4)}$$

where d_t is the diameter of the tunnel and m_l is the linear mass density of the discharged material along the drift.

Substituting for m in the expression for C_p gives Equation 11-5,

$$C_p(x; m_l, \phi, d_t) = \frac{m_l}{\pi^{3/2}\,(0.4)^{1/2}\, d_t \phi x} = 0.284 \frac{m_l}{d_t \phi\, x} \qquad \text{(Eq. 11-5)}$$

Using limits previously derived (CRWMS M&O 1995d) for C_p at the closest potential WE location, i.e., 0.1 ppm of DOC; 1 ppm for NO_3^-; and 3.7 ppm for $SO_4^=$, the distance x =15 m, the drift diameter d_t = 5.5 m and the an approximate matrix porosity for the WE zones (Marshall and Holmes 1979) $\phi = 0.1$.

In addition, Fluorine and other halogen-bearing salts are also naturally occurring in the repository horizon and can be measured at a quantifiable level. Using the natural variance for Fluorine as 0.29 ppm (Harrar et al. 1990) and other halogen-bearing salts as 0.61 ppm (Harrar et al. 1990), limits can be calculated using the same rational as above.

Therefore, the limits for negligible impacts on committed quantities for these constituents in Phase II of the ECRB Cross Drift are provided in grams per linear meter (g/m) in Table 11.1 below:

Table 11.1. Phase II ECRB Cross Drift Recommended Limits (g/m)

DOC	NO_3^-	$SO_4^=$	Fluorine	Halogen-Bearing Salts
2.9	29.	107.	8.4	17.7

11.3.6 Committed Substances in the ECRB Cross Drift Phase I

The ECRB Cross Drift Starter Tunnel and Phase I of the ECRB Cross Drift are a total of approximately 773 m long, beginning from the left rib of the ESF North Ramp at approximately Station 19+92 m and ending at the cross over with the TS Main Drift.

11.3.6.1 Committed Organic Substances

Scaling the CRWMS M&O (1995d) analysis for the smaller diameter ECRB Cross Drift yields an organic limit of 6.51 g/m at a 37 m offset (at the closest distance to potential WE expansion areas for Phase I of the ECRB Cross Drift) as a conservative organic limit for the entire length of

Phase I of the ECRB Cross Drift. There should be no significant waste isolation effects (1) due to the large offset between Phase I of the ECRB Cross Drift and any WE areas, and (2) since organic use during Phase I construction is not expected to exceed these limits except during a 50-m testing interval (see Sections 6.4 and 11.3.5 of CRWMS M&O 2000a).

It should be reiterated here that this evaluation does not indicate that an impact to waste isolation will occur if these limits are exceeded, but only that the potential for impacts to waste isolation exist. However, controls developed from constraints on potential impacts from this case are expected to minimize impacts from any reasonable flow scenario (this excludes the worst-case of disequilibrium fracture-flow).

11.3.6.2 Committed Inorganic Substances

Based on a previous analysis contained within the Subsurface ESF DIE (Equation 11-6), substituting in minimum offset distance and tunnel radius (R) for the ECRB Cross Drift provided general constraints for the total source constraints on NO_3^- and $SO_4^=$. These limits are spatially dependent, so the limits for which potential WE zones are at the minimum 37-m offset from the TS Loop were used to constrain the potential waste isolation impacts from the ECRB Cross Drift.

$$C_p(d,h,\phi) = \left[\frac{d}{\phi(4\pi h a_x)^{\frac{1}{2}}} \right] \qquad \text{(Eq. 11-6)}^3$$

where,

C_p = the peak concentration at the closest waste package ($\cong$ 0.1 ppm)
d = the mass density (grams per m^2)
ϕ = the porosity ($\cong$ 0.1)
h = linear distance to the closest waste package (m)
a_x = dispersion in the x direction (1/10 of linear distance) (m)

Therefore, the conservative limits for negligible impacts on committed quantities for these constituents in Phase I of the ECRB Cross Drift are provided in Table 11.2 below.

Table 11.2. Phase I ECRB Cross Drift Recommended Limits (g/m)

DOC	NO_3^-	$SO_4^=$
6.51	65	241

[3] Note: The source of Equation 11-6 is CRWMS M&O (1995d), Attachment II, Equation 17.

11.3.7 Committed Substances in the TS Loop

11.3.7.1 Inorganics in the TS Loop

A previous evaluation of committed components from diesel exhaust (sulfur oxide gases, nitrogen oxide gases, and diesel particulate matter) and other sources was performed in the Subsurface ESF DIE (CRWMS M&O 1999a). Controls were set at a level of that the local perturbations to the near-field water compositions at the closest waste package were kept at or below a value of 10 percent of ambient concentrations of their corresponding dissolved constituents ($SO_4^{=}$, NO_3^{-}). The previous analysis assumed that the major impact for peak concentration perturbation at any point is due to the source density associated with the closest portion of the tunnel. Therefore, the limits for negligible impacts on committed quantities for these constituents in the TS Loop are given in Table 11.3:

Table 11.3. TS Loop Recommended limits, (g/m)

NO_3^{-}	$SO_4^{=}$
96.	350.

The total inorganic releases from all sources will not impact potential radionuclide release and transport over a 10,000 year time period, provided that the local perturbations to the near-field water compositions at the closest waste package are kept at or below a value of 10 percent of ambient concentrations of these dissolved constituents.

11.3.7.2 Organics in the TS Loop

Previous bounding calculations were performed to determine the potential influence of retained organic substances in the TS Loop (CRWMS M&O 1999a) and to generate controls that should result in negligible impact to waste isolation from use of committed organic materials. In that general analysis, the retained organic materials were assumed to completely dissolve as organic carbon and migrate toward the closest potential waste package emplacement sites. All committed organic fluids and materials were considered as indistinguishable. Controls outlined in the Subsurface ESF DIE (CRWMS M&O 1999a) specify an input of 10 g/m within the Main Drift of the TS Loop, as the limit for expected negligible impact on waste isolation. This limit was based on the criterion that the local perturbations to the near-field DOCs at the closest waste package were kept at or below 10 percent of ambient concentrations. The negligible impact level for DOC was defined as local perturbations of 0.1 ppm (CRWMS M&O 1994c, 1999a). In those evaluations, it was assumed that:

1) The retained organic material represents a point source.

2) The dissolution of the organic point source is complete and instantaneous.

3) Dispersion of the organic source occurs via saturated flow toward potential WE zones.

4) No reactions to degrade the concentration of total DOC occur.

These evaluations concluded that, for the TS Loop (CRWMS M&O 1994c, 1999a):

1) If the total retained organic materials in the Starter Tunnel and Alcove #1 is less than 420 kg, it is expected that there should be negligible impact to the geochemistry of groundwater within the Potential Expansion Areas Boundary (i.e., perturbations to fluid compositions should be less than 0.1 ppm DOC).

2) If the total retained organic materials in the ESF Starter Tunnel and Alcove #1 is less than 2500 kg, it is expected that the impact to the geochemistry of groundwater within the Proposed Repository Outline should be negligible, although there is some potential for impact to the groundwater geochemistry within the Potential Expansion Areas 2, 3, and 6.

3) If the total committed DOC was kept at or below the following for the TS Loop: 95 g/m from Station 0+00 m to 13+11 m, 28 g/m from Station 13+11 m to 18+59 m, 13 g/m from Station 18+59 m to Station 24+08 m, and 10 g/m for the remainder of the tunnel, it is expected that there should be negligible impact to the waste isolation capabilities of the potential repository.

11.3.7.3 Aqueous Dyes

Aqueous dyes including: FD&C Blue No. 1 (food color); FD&C Red No. 40 (food color); FD&C Yellow No. 5 (food color); FD&C Yellow No. 6 (food color); Amino G Acid; Fluorescein, Lissamine (acid Yellow 7); Pyranine; Rhodamine B; Rhodamine B Sulfo; and Rhodamine WT are organically based compounds; therefore, their potential to impact waste isolation has been evaluated. For the purposes of this evaluation, these aqueous dyes are conservatively determined to be committed TFMs because the solutions are injected directly into the rock.

Analyses discussed in Section 11.3.3, the Subsurface ESF DIE (CRWMS M&O 1999a) specifies an input of 10 grams of organic matter per linear meter of tunnel, within the Main Drift of the TS Loop, as the limit for expected negligible impact on waste isolation. With the proposed niche length of approximately 5 m, the limit on total organic matter retained per niche is approximately 50 grams for expectation of negligible impact on waste isolation.

The use of dyes during testing in Niches #1 and #2 were proposed in Mitchell (1997a). These testing activities would yield a maximum total of 588 grams for committed organics in Niche #1, based on the input of 42 liters of food color dyed water at 10,000 ppm (about 10 grams/liter) and an input of 84 liters of fluorescent dyed water at 2,000 ppm (about 2 grams/liter). For Niche #2, the total committed organics would be 168 grams (Mitchell 1997a), with an input of 14 liters of food color dyed water at 10,000 ppm (about 10 grams/liter) and 14 liters of fluorescent dyed water at 2,000 ppm (about 2 grams/liter). In both Niche #1 and Niche #2, the organic limit of 50 grams per niche (based on 10 g/m of tunnel, CRWMS M&O 1999a) would be exceeded by the proposed TFM usage. More specifically, the total committed organics for Niche #1 and Niche #2 are factors of approximately 12 and 3 times the recommended limits, respectively. Similar quantities of aqueous dyes have been proposed for Niches #3 and #4, per Mitchell (1997b), but are redistributed per Mitchell (1998a).

It should be noted that because of the conservative nature of the original calculation in CRWMS M&O (1999a), committed organics in excess of 50 grams per niche does not ensure that an impact to waste isolation will occur, only that the potential for impacts to waste isolation may exist. The limit on retained organics indicates the value below which negligible impact to waste isolation is expected at the closest waste packages. Retained organics exceeding this value may have some undefined impact to waste isolation at the closest waste packages which would decrease with distance from the injection site. Given the limited total mass of organic material involved in the tests evaluated above (maximum of approximately 756 grams of organics for each pair of niches), only a relatively small area of the potential repository block could experience dissolved organic carbon values exceeding the above criterion. As stated above, such areas are not ensured of having impacts on waste isolation, but controls should be implemented to minimize potential impacts.

11.3.7.4 Fluorinated Organics, Fluorine Salts, and Non-Fluorine, Halogenated Salts for use in Alcoves and Niche Testing

Due to numerous qualitative issues concerning the presence of Fluorine (F^-) and related complexes (e.g., hydrofluoric acid [HF]) at or near potential WE areas (e.g., enhanced degradation of spent fuel cladding material and/or waste package materials) use of such materials has been previously restricted to only gaseous compounds. Since Fluorine is naturally occurring in the repository horizon and can be measured at a quantifiable level, we may use the same rationale as that applied to dissolved organics in Section 11.3.5. Similarly, an analysis for other halogen-bearing salts has been performed. These analyses result in recommended limits on the total mass of Fluorine, other halogens, and organics committed to the geosphere for alcove slot cuts. It is recommended that the use of these elements and compounds be limited to the quantities identified below to avoid potential waste isolation effects.

Inorganic and organic tracers, which contain Fluorine or other halogen constituents (i.e., tracers containing bromide, chlorides, or iodide), have been proposed for use in selected Alcove #8, Alcove #4 and #6 slot cuts, and selected niches (Section 6). Previous analyses have used the natural variation in concentration of a dissolved material as the limiting factor for use in site characterization activities (CRWMS M&O 1999a, 2000a). In particular, the expected dissolved concentration of the introduced material at the closest WE location has been used to gauge whether the use of the material will have a noticeable affect on performance. The basis of the argument is that if the local concentration of some solute that is naturally present is not changed by more than the natural variation in such concentration (here we use the standard deviation of the concentration), then the effect of this change on potential repository performance will be negligible. In the case of Alcove #4 and #6 slot cuts, Alcove #6 is closer to potential WE areas. Therefore, an analysis of Fluorine and organic tracer materials that may become committed in Alcove #6 is expected to bound the potential effects on performance for the use of Fluorine and organic tracer materials in Alcove #4.

The analysis uses the one-dimensional advection-dispersion analysis used in Section 11.3.5. The natural variation in Fluorine is found to be 0.29 ppm (Harrar et al. 1990), and the natural variation in dissolved organic material is 0.1 ppm. Other halogen-bearing salts may be evaluated based on the natural variation in chloride content, which is found to be 0.61 ppm (Harrar et al.

1990). Given an offset from the nearest potential WE location of at least 92 m (for Alcove #6 slot cut) and 32 m (for Niche #2), we may use Equation 11-6 in Section 11.3.6 to compute the limiting surface concentration that could be allowed in Alcove #6 testing to be 3 grams per square meter (g/m^2) for Fluorine, 1 g/m^2 of organic material, and 6 g/m^2 of total halogen ion surface concentration excluding Fluorine and in Niche #2; 1.04 g/m^2 for Fluorine, 0.36 g/m^2 of organic material, and 2.2 g/m^2 of total halogen ion surface concentration excluding Fluorine. In the analysis, the tracer is presumed to be discharged onto a surface from which point the tracer is assumed to completely dissolve in the existing rock water and migrate towards the nearest point of potential WE. To use this analysis, we must consider that the tracer is injected into a borehole that lies above an opening for capturing the downward moving water and tracer solution. The dimensions of this volume between the injection point and the point of discharge for Alcove #6 is approximately 2 m, and the plan-view footprint of the proposed test bed is at least 3 m by 3 m. Thus, the tracer may be considered to be injected into an approximate 18 m^3 volume of rock comprising the test area for slot cut testing. For Niche #2, the length of the borehole is approximately 5 m, the width of the niche is approximately 4 m, and the height above the crown is approximately 0.75 m so the volume of rock comprising the test are is 15 m^3.

We would like to compute how much mass injected into this volume is equivalent to the surface concentration limits already derived. This is done by computing the maximum concentration passing the "end" of the test volume, assuming a surface concentration deposited on one surface of the test bed prismatic volume. Once this maximum concentration is established, then we may set the mixed concentration within the test bed to this maximum concentration and derive a maximum total tracer mass. Again, we use Equation 11-6 of Section 11.3.6, this time to compute the maximum concentration that passes the far edge of the test bed. To simplify the dimensional dependence on the geometry of the test, the equivalent dimensions of a cube with the same volume are used. Thus, for the Alcove #6, a cube with a volume of 18 m^3, and for Niche #2, a cube with a volume of 15 m^3, that is approximately 2.62 m (for Alcove #6) and 2.46 m (for Niche #2) from the hypothetical surface that the tracer is deposited. This calculation gives maximum concentrations for Alcove #6 of 10.2 grams per cubic meter (g/m^3) (ppm) for Fluorine, 3.4 g/m^3 of dissolved organic material, and 24.4 g/m^3 of dissolved halogens (other than Fluorine) and for Niche #2; 3.77 g/m^3 for Fluorine, 1.31 g/m^3 of dissolved organic material, and 7.97 g/m^3 of dissolved halogens (other than Fluorine). Given these concentrations for Alcove #6 and the water volume of the test bed, 1.8 m^3, we find the limiting mass of committed tracer elements or compounds to be 18 g of Fluorine, 6 g of organic material, and 39 g of halogens (other than Fluorine). These limits, derived for Alcove #6, may be conservatively applied to Alcove #4 because of its greater offset from potential WE locations. Given the above concentrations for Niche #2 and the water volume of the test bed, 1.5 m^3, we find the limiting mass of committed tracer elements or compounds to be 5.7 g of Fluorine, 2 g of organic material, and 12 g of halogens (other than Fluorine).

The main injection test area for Alcove #8 (30 m offset) is a couple meters closer to potential waste emplacements than Niche #2 (32 m offset). Previously, tracer limits for Alcove #8/Niche #3 testing were established using equation 11-6, which determined conservative limits based on one-dimensional advective-dispersive transport from the discharge location to the nearest potential WE drift (30 m). However, current modeling (BSC 2001) performed by LBNL shows that a tracer plume from the injection test area is limited to 20 m in the horizontal direction and

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that the tracer plume will be washed out of the potential repository within 10,000 years in the vertical direction. The results of this model are significant in that it shows that traced water injected into Alcove #8 should not reach proposed Waste Emplacement drifts. Therefore, based on this model the tracer concentrations and quantities identified in Section 6.10.5 can be used with negligible impacts expected to the potential repository. As such no new QA controls are required, however, use of tracers greater than those amounts expressed in Section 6.10.5 would require further SA evaluation.

Tracers from previous testing activities are present in the rock just above Niche #3. The water added from Alcove #8 could potentially mobilize these tracers. It is likely that some of the mobilized tracers will be recovered in Niche #3, however, some of the tracers may migrate around the niche due to the capillary barrier effect and/or anisotropy in the rock properties. Nevertheless, this represents a relatively minor concern due to the relatively small total quantities involved and the probabilities of mobilization beyond the excavation zone that would remove these tracers.

The above evaluations of commitable quantities of organic and inorganic constituents consider the transport of these constituents from the source directly to the closest waste package. The current UZ flow model used for site scale UZ and thermal loading for the TSPA is bounded on the east by the Bow Ridge Fault (CRWMS M&O 1998c). The site scale model boundaries were defined in such a way as to fully bound the UZ system for the potential repository and potential UZ radionuclide pathways. Any moderate perturbations in the UZ outside the model boundaries are interpreted to have no effect on the UZ Site scale model. Thus, the proposed use of large quantities of inorganic tracers in conjunction with infiltration testing above Alcove #1 should not result in any waste isolation effects on the waste package performance or effect the ambient conditions in the near-field or UZ at potential waste WE areas. However, eventual transport of these committed tracers through the UZ into the SZ will place these constituents within potential radionuclide pathways and therefore must be evaluated in terms of their potential effect on the SZ transport.

Equation 11-6 is the analysis result of using a one-dimensional advection-dispersion equation. Given a 731 m offset from the SZ to the site surface above Alcove #1, 78.2 m^2 test area above Alcove #1 and a natural variation for each anion as defined from J-13 water analysis (Harrar et al. 1990) (again for Br and I, the variation in Chlorine is used), the limiting surface concentration that could be allowed which would result in a perturbation of the SZ concentration less than the natural variance is 50 g/m^2 for Chlorine, Bromine, and Iodine and 23.8 g/m^2 for Fluorine. It is expected that some percentage of the traced water released in conjunction with Alcove #1 testing should be recovered, however, to meet the source density limit of 50 g/m^2, greater than 99 percent of the Chlorine based tracer would have to be recovered. If these tracers are committed in the quantities as proposed, the maximum area of the SZ that could potential be perturbed in excess of the natural variance can be calculated by rearrangement of Equation 11-6 to solve for d (source mass density) and division of the total mass released by the source mass density. Table 11.4 yields the maximum area potentially effected in the SZ by increased concentrations of Chlorine, Bromine, Fluorine, and Iodine. The maximum perturbed area of the SZ is 7350 m^2 (7.35×10^{-3} square kilometers) resulting from Chlorine released in conjunction with Alcove #1 testing. Given that the accessible environment boundary is at least 20 kilometers away from the potential repository, and the repository is at least 3 kilometers wide (CRWMS M&O 1994a) a conservative estimate of the total SZ area that would be affected by radionuclide release is 60 square kilometers, thus only 0.0125 percent of the total SZ area could potentially be effected by increased concentrations of these anions. With limited recovery of a portion of the tracers used in Alcove #1 testing, the affected area of the SZ realizing perturbed concentrations of these ionic species is expected to be negligible.

Table 11.4. Maximum SZ Area Potentially Affected by Proposed Alcove #1 Tracers

Ion	Proposed Mass for Alcove #1 (kg)	Std. in J-13 water (ppm)	Potentially effected SZ Area (m^2)
Chlorine	367.0	0.61	7350
Bromine	260.0	n/a	5210
Fluorine	16.0	0.29	674
Iodine	5.09	n/a	102

It should be noted that because of the conservative nature of the bounding analyses the committal of tracers in excess of the recommended limits does not ensure that an impact to waste isolation will occur, only that the potential for impacts to waste isolation may exist. The referenced organic and Fluorine limits indicate the values below which negligible impact to waste isolation is expected at the closest waste packages or potential radionuclide pathways. Committed substances exceeding these values may have some undefined impact to waste isolation at the closest waste packages or along potential radionuclide pathways that would decrease with distance from the injection site. Given the limited quantities of tracers to be used for both the niche studies and the alcove studies, only a portion of the potential repository, expansion areas, or potential radionuclide pathways could experience some impact to waste isolation. As stated above, such areas are not guaranteed to have impacts on waste isolation, but controls should nevertheless be implemented to minimize the potential impacts.

11.3.7.5 ECRB Cross Drift Niche Studies

The niche tracer testing performed in CRWMS M&O (2000c) (In Situ Field Testing of Processes, ANL-NBS-HS-000005, Rev. 00) showed tracer migration to be localized and possibly confined to a small area directly below the liquid-release interval. In addition, spatial distributions of other dye tracers resulting from earlier liquid release tests consistently pointed to localized flow with limited lateral spreading of tracer migration. Based on the results of these tests excavation or mining out is assumed to be a viable option for tracer removal. Therefore, it is possible to use tracer quantities greater than the limits required by Section 13 of this DIE provided that the tracers are mined out prior to waste emplacement.

11.3.8 Thermal Testing Facility

The thermal test will also affect geochemical conditions within the heated region. However, the heated region is not expected to extend further than about 40 m laterally and about 40 m vertically from the drift center line (Buscheck and Nitao 1995, p. 37). Therefore, the changes in geochemical conditions induced in the testing area are not expected to affect the potential performance of the closest potential repository waste package emplacement locations that are offset laterally a minimum of 114 m.

11.3.8.1 Organics within the Thermal Testing Facility

Materials identified for use in CRWMS M&O (1996b) include insulation materials, silicone sealers, PVC/Chlorinated Polyvinyl Chloride (CPVC) solvents, adhesives, copper sulfate electrodes, paints, and grouts. These materials are planned to be non-committed (Weaver 1996b), with the exception of unknown quantities of spray paint used to mark locations in the drift. Appropriate limits for the quantities of paint and incidental losses of other organic materials are identified in CRWMS M&O (1999a) such that these releases have a negligible effect on potential repository performance. Because of the larger offset of the Heated Drift, these impacts are bounded by the limits applicable to the Main Drift of the ESF (CRWMS M&O 1999a).

11.3.8.2 Inorganics within the Thermal Testing Facility

The Heated Drift will also include the use of cast-in-place concrete for an invert floor as well as a full liner for a portion of the heated drift section (see Section 6.11.4). Water is a component of the concrete mixture, and due to the heating anticipated, an unquantifiable amount of this water may be volatilized and released to the geosphere. Therefore, water used for concrete should be conservatively counted as water lost in the Heated Drift, which is consistent with the evaluation in the DIE for the Subsurface ESF (CRWMS M&O 1999a). The concrete is planned to be temporary; therefore, all other materials used in the concrete are expected to be removed before potential repository operation, and negligible impact is expected for this temporary material on potential repository performance.

11.3.8.3 Fire-Suppression Materials in the Thermal Testing Facility

The fire-suppressant material specifically designed for use within the Thermal Testing Alcove instrument building is the chemical trade named FM-200®, which represents a potential source of committed organic constituents. The FM-200® fire-suppressant material is predominately comprised of Heptafluoropropane (CF_3CHFCF_3), a liquefied compressed gas. The fire suppressant delivery system is designed to release a maximum of 58 pounds of material within the TTF Instrument Building to contain any potential fire. This gaseous release should be contained within the building and/or removed from the ESF tunnel by the air ventilation system. There is a potential that some of the material will be adhered to equipment and could be removed in the cleanup of that equipment or removal of the entire instrument building and its contents from the ESF. If water is used in conjunction with the release of the gaseous fire-suppression material, due to the materials high solubility (260 milligrams/liter), the water could wash the chemical into fractures, and most of the material would become potentially committed to the environment. It is recommended, therefore, that water be used in conjunction with this fire-suppression material only if necessary for safety. In addition, the use of this fire suppressant material has been evaluated for use within the TTF Instrument Building, a free standing enclosed structure that should contain any residue that may be left from the gaseous release, and therefore this chemical should only be used as evaluated herein.

11.3.8.4 After the Fact Evaluation of Hydrofluoric (HF) Gas Generation in the Thermal Test Facility Hydrologic Boreholes BH 60 and BH 77 (ESF-HD-HYD-4 and 9) (YMP 1997d)

Hydrofluoric gas was inadvertently generated during testing activities in the TTF hydrologic test boreholes BH 60 and BH 77 . The generation of this gas was determined to be caused by the high temperature effect on the fluoroelastomer rubber (Viton™) packer assemblies that were used to seal and isolate portions of each borehole. The laboratory tests indicated that fluoroelastomer rubber at high temperature (above 150°C) was the only significant source of HF.

A total number of four packers deflated in boreholes BH 60 and BH 77. Three of these packers are in borehole BH 60 and one is in borehole BH 77. The packers have failed over the past four years, possibly due to the roughness of the borehole walls, the sustained high temperature environment, or chemical degradation of the material. Borehole BH 60 contained four packers at depths of 4.6m, 10.7m, 22.0m, and 28.1m from the collar. The three deepest packers nearest to the wing heaters contain fluoroelastomer material, whereas the shallowest packer is Neoprene™ based. All three of the fluoroelastomer packers in borehole BH 60 have deflated. Borehole BH 77 contains three packers, two of the deepest contain a fluoroelastomer. Only the deepest packer, at a depth of 17.1m, deflated (DOE 2002).

Borehole BH 72 (ESF-HD-CHE-9, YMP 1997d) was used to conduct in-hole testing of the effects of high temperature on fluoroelastomer packer samples introduced into the borehole. Water samples collected from borehole BH 72 at high temperatures (~170°C) prior to introduction of any fluoroelastomer rubber or Teflon™ show pH values in the range 4.8 to 5.5 and fluoride concentrations well below 1 ppm over a period of six months. These characteristics are typical of condensing Drift Scale Test steam that contains only some dissolved carbon dioxide generated by water-mineral-gas reactions in the rock. With the introduction of the fluoroelastomer packer materials and Teflon™ sampling tube in borehole BH 72, the pH of the water samples dropped to 3.8, while fluoride rose to 2.4 ppm within three days. Nine days after introduction of the fluoroelastomer rubber and Teflon™ in borehole BH 72, fluoride concentrations reached as high as 7.6 ppm for a sample with a pH of 3.4 (DOE 2002). The test reproduced the earlier finding of HF gas in boreholes BH 60 and BH 77 and showed that the gas was being generated in-hole by emplaced packer material.

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This after-the-fact evaluation looks at the reaction of the HF gas or acid solution produced by the packer material and the chemical reaction of this acid with the surrounding rock. As the HF gas diffuses through the rock matrix it will react directly with the rock or dissolve into the available pore water contained in the rock. As this occurs, the acid solution formed will in turn react with surrounding minerals and be neutralized. The purpose of this evaluation is to show that the acid will completely react with it's immediate rock environment and be neutralized instead of being transported through the unsaturated zone to other test areas or proposed waste emplacement areas where it could cause adverse impact.

The amount of HF gas that was released by the fluoroelastomer is unknown and is conservatively estimated as the mass of the four rubber packers that were known to have failed. The cylindrical dimensions of a standard packer was measured by the author and is approximately 2.75 inches in diameter by 28 inches long by 0.2 inches thick. The weight of the fluoroelastomer material in one packer is estimated as follows:

Weight of fluoroelastomer packer = Volume of packer material x specific gravity of packer material x specific weight of water

$$Volume = V1 - V2$$

$$V1 = (28)\,\pi(2.75/2)^2 = 166\,in^3$$

$$V2 = (28)\,\pi((2.75-.4)/2)^2 = 121\,in^3$$

$$Volume = 166\,in^3 - 121\,in^3 = 45\,in^3$$

$$45\,in^3 x\ 4 \text{ packers} = 180\,in^3$$

Specific gravity of packer material = 1.82 (Dupont Dow Elastomers, 1998)

Specific weight of water @ STP = 62.4 lbs/ft^3

Weight of gas released ≅ Weight of packer material ≅

$$180\ in^3 \times 1.82 \times 62.4\ lbs/ft^3/1728\ in^3/ft^3 = 12\ lbs$$

This is a conservative estimate of the total amount of released gas since only some fraction of the total weight of the packers is HF. The approximate weight of HF generated is then used to determine the approximate amount of rock that would be required to react with and neutralize this amount of acid. An approximation of the amount of rock required to neutralize this amount of acid can be determined using known chemical reaction equations between the HF and rock minerals. The most abundant mineral in the Tptpmn at this location are the feldspar minerals. An idealized reaction equation involving sodium feldspar (albite) and HF gas has been provided via e-mail by C. Steefel (Steefel C. 2002), Lawrence Livermore National Laboratory (LLNL).

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$$2\ NaAlSi_3O_8 + 2\ HF(g) + H_2O = 4\ SiO_2 + 2\ Na^+ + 2\ F^- + Al_2Si_2O_5(OH)_4$$

Albite	Hydrogen Fluoride	Quartz	Kaolinite

Shown above is a representative idealized reaction showing the consumption of HF(g) due to reaction with feldspar (albite in this case). The effect of the reaction is to break down the hydrogen fluoride gas, consuming hydrogen ion and releasing fluoride into the aqueous phase. This reaction is known to be rapid, based on the fact that the HF is routinely used to dissolve feldspars. The identity of the secondary mineral phase (quartz and kaolinite) is somewhat uncertain, but this is the most likely scenario. Any secondary phase formed from reacting acid with feldspar will have the effect of consuming hydrogen ions and thus breaking down the HF.

The various possibilities for different reaction stoichiometries won't have a large effect on the consumption of the HF (Steefel C. 2002).

Thus, an approximation of the quantity of rock that is needed for complete neutralization to occur can be determined by the stoichiometric ratio of the chemical reaction equation. Looking at the above equation we see that two moles of HF gas combines with two moles of $NaAlSi_3O_8$ (albite feldspar) for complete neutralization and subsequent release of aqueous sodium, aqueous fluorine, silica and clay minerals. The approximate weight of the rock necessary for complete neutralization is determined using the molecular weights of each element as follows :

Moles of HF gas = HF = 1 + 19 = 20.0 g/mol
Mole of $NaAlSi_3O_8$ = 23 + 27 + 28(3) + 16(8) = 262 g/mol

Stoichiometric ratio = 262/20 = 13.1

So every pound of HF gas requires 13.1 lbs of $NaAlSi_3O_8$ (albite feldspar)

An approximation of the percentage of feldspar minerals for the rock located in the Heated Drift was made by using data from borehole SD-9 at a depth representative of the drift location and in the Tptpmn unit. Borehole SD-9 is located approximately 100 m west of the Thermal Testing Facility Heated Drift. The borehole data shows that the percentage of feldspar mineralization in SD-9 between 221.5 m and 259.7 m (CRWMS M&O 1996) is approximately 55 percent (CRWMS M&O 1998f). Knowing this percentage and the quantity of HF that has been released to the rock, the approximate amount of Tptpmn host rock required for complete neutralization of the HF can be determined. Using 12 lbs of HF then requires

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12 lbs HF (gas) $\times$ 13.1 $\div$ 0.55 = 286 lbs of rock

The calculated weight of rock that is needed to completely react with and neutralize the HF is a conservative estimate because it is solely based on the amount of feldspar available for reaction. The HF will also react with other alkaline based rock minerals including mica and clays that are formed through the alteration of feldspars and exist in the Tptpmn unit in smaller quantities (CRWMS M&O 1998f). The reaction involved in these other minor rock minerals, for example mica reacting with sodium and potassium feldspars, are shown to form hydrolyzed silicates of muscovite and paragonite (mica minerals) due to alteration of the host rock (Guilbert, M., Park, F. Jr. 1999, pp 177,180):

$$3KAlSi_3O_8 + 2H^+ \Leftrightarrow KAl_3Si_3O_{10}(OH^-)_2 \text{ (muscovite)} + 6SiO_2 + 2K^+$$

$$3NaAlSi_3O_8 + 2H^+ \Leftrightarrow NaAl_3Si_3O_{10}(OH^-)_2 \text{ (paragonite)} + 6SiO_2 + 2Na^+$$

Furthermore, the hydroxide ion OH^- from each of these altered minerals combines with the hydrogen ion provided by the HF to form a fluorosericite and water as shown in the equation given by Guilbert.

$$OH^- \text{ mica} + HF \Leftrightarrow F\text{- mica} + H_2O$$

Considering the distance to the closest proposed repository emplacement drift of approximately 114 m (Section 6.11.4), significant transport of HF to emplacement areas is not probable because of the acid's high reactivity with the surrounding rock and the small amount of rock necessary to completely neutralize it. The calculations and discussions, above are based on conservative approximations and show that no adverse impacts should occur due to the inadvertent formation of HF gas from the test boreholes BH 60 and BH 77 to permanent items or testing activites, with the exception of activities cut short because of failed fluoroelastomer packers. To date, other tests conducted in the Thermal Testing Facility have not been impacted by the release of HF in the subject boreholes. (Jones R. 2002).

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In future testing associated with performance confirmation, where boreholes could be located in or near emplacement drifts, the probability of adverse impacts would increase. For this reason, a requirement (Requirement #17) is established by this DIE that prohibits the use of fluoroelastomer rubber hardware from being used in drill holes where the hardware could be exposed to elevated temperatures higher than 100° C without further Safety Assurance Department evaluation. This requirement does not apply to existing hardware that is currently installed in test boreholes in Alcove #5.

11.4 THERMAL/MECHANICAL EVALUATIONS

The previous evaluation of potential impacts to waste isolation caused by thermal-mechanical perturbations resulting from retained TFM and from excavation methods in the North Ramp (CRWMS M&O 1995d) indicated that:

1) the potential effects of committed substances on TM characteristics of natural barriers or engineered items in the North Ramp tunnel are expected to be negligible if the substances do not interfere with the emplacement and performance of North Ramp tunnel seals (at the time when sealing plans for the tunnel are prepared, further analysis of potential impacts to waste isolation should be performed);

2) there is a negligible impact on the overall waste isolation capability of the entire potential repository due to the generation of preferential aqueous pathways through the mechanically disturbed zone;

3) movement of underground fluids along the sealed ramp (and its surrounding mechanically disturbed zone) should have a negligible impact on the waste isolation capability of the potential repository;

4) to minimize the potential impact of the mechanically disturbed zone induced by the excavation, the TBM method, which results in a smaller disturbed zone compared to the drill-and-blast method, is recommended for the primary excavation method for ESF construction; and

5) regardless of the excavation method used for North Ramp, no potential impacts to waste isolation resulting from the lack of a specified stand-off distance for boreholes

were identified, because boreholes will be sealed both above and below the potential repository horizon.

Because sealing issues are identical for the North and South Ramps and the previous evaluation analyzed the potential impacts from excavation methods in a general and spatially *independent* manner, the recommendations for negligible impact limits from the Package 2C evaluation summarized above can be applied directly to the entire TS Loop. If these recommendations are followed, then it is expected that there will be negligible impact to waste isolation capabilities of the site due to construction and operations conducted throughout the entire TS Loop.

A TM stability analysis was also performed to investigate the potential effects of the presence of the ECRB Cross Drift on WE Drift stability (CRWMS M&O 1998d). Parallel orientation of the ECRB Cross Drift and WE Drifts were assumed for this analysis. This includes the worst case condition in which ECRB Cross Drift is parallel to and directly overlies a WE Drift. Under isothermal conditions, the maximum difference in closure with and without the ECRB Cross Drift is predicted to be within 1 mm, and in all cases predicted that the difference in closure would be less than 10 percent of that expected without the ECRB Cross Drift. The maximum difference in tangential stress nearest the WE Drift wall is predicted to be within 0.5 megaPascals. These differences are less than 10 percent of the tangential stress predicted without the ECRB Cross Drift. Similarly, small changes in closure and tangential stress were found over time with an 85 Metric Tons Uranium per acre thermal load included in the analysis. Finally, the effects of seismic loads were also investigated. The presence of the ECRB Cross Drift was found to have a negligible effect on the behavior of the WE Drifts in response to seismic ground motions.

11.4.1 Hydrologic Testing Activities/Hydrofracturing

Activities associated with hydraulic fracture testing include borehole drilling, insertion of straddle-packer elements (water inflatable packing bladders), and core sampling. Borehole drilling is addressed below in Section 11.4.2. Hydrofracturing of the borehole by inflation of straddle-packer elements is expected to have negligible impact on the waste isolation capabilities of the site, due to the local nature of the fracturing, and any effect of this fracturing (i.e., creation of preferential pathways) would be overshadowed by the borehole excavation itself. Water loss from hydrofracturing activities is subject to the linear water loss limit for excavations associated with TS Loop and ECRB Cross Drift (CRWMS M&O 1999a, 2000a), including the use of LiBr tracer.

11.4.2 Borehole Drilling

Borehole drilling in testing alcoves and niches for testing related activities, consolidated sampling, or installation of ground support, has been identified as a potential waste isolation concern and is evaluated in the following section.

The potential for the creation of preferential pathways by the drilling of boreholes is bounded by the evaluation of drilling rockbolt holes in the Subsurface ESF DIE (CRWMS M&O 1999a), because of the length and diameter of most testing related boreholes are insignificant relative to the size of the ESF tunnel itself. Review of the repository interface drawings (CRWMS M&O

1994a) indicates that the distance from the proposed borehole locations to potential waste package emplacement drifts is still well beyond the waste package offset distance assumed in the Subsurface ESF DIE (CRWMS M&O 1999a). However, any proposed testing boreholes that have not been previously evaluated and/or differ significantly in length and diameter from previously evaluated boreholes must be reviewed to ensure their installation does not create a waste isolation concern.

Water loss from borehole drilling in testing alcoves and niches during wet drilling is subject to the linear water loss limit for excavations associated with ESF Tunnel (CRWMS M&O 1999a), including the use of LiBr tracer. Any water used as well as any other TFMs emplaced during borehole drilling activities must be reported to the TFM database for evaluation of the potential waste isolation impacts of that specific retention within future Performance Assessment evaluations.

Dry drilling activities typically are performed with compressed air traced with SF_6 or tetra fluoroethane (CH_2FCF_3) gases (Section 11.3.1) to avoid test interference during test configuration and setup. Dry drilled boreholes for testing or confirmation drilling activities are expected to have negligible waste isolation effects provided the proposed locations of the boreholes have been evaluated as addressed above. Use of Well-Guard, a drill pipe thread lubricant manufactured by Jet-Lube has been determined to be acceptable as long as operational practices remove any excess from the outside surface of the drill pipe, and to the extent practical limit the amount of Well-Guard used on the drill pipe threads to that amount needed to facilitate assembling the drill pipe sections. Any quantities of the Well-Guard lubricant which may be lost on the borehole wall surfaces, need to be estimated and routinely reported in accordance with AP-2.17Q.

11.5 MISCELLANEOUS TESTING RELATED ACTIVITIES

11.5.1 Alcove #2 Exhibit Area

Installation of additional ground support (e.g., walk ways), exhibition materials, and sound system are not believed to have any waste isolation effects as these items are non-permanent and are expected to be removed before the site closure. The use of concrete and associated admixtures for construction activities has been previously evaluated within theSubsurface ESF DIE (CRWMS M&O 1999a). Therefore, negligible waste isolation effects are anticipated from the use of Alcove #2 as an exhibit area due to the non-permanent nature of the items to be installed, and the large offset of this alcove from the potential WE areas.

11.5.2 Geologic Mapping

Waste isolation concerns with activities associated with geologic mapping are addressed in the sections above and within the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). These activities are not expected to affect the waste isolation capabilities of the potential repository, providing water used for washing the tunnel walls is subject to the water use limits, including the use of LiBr tracer, addressed within CRWMS M&O (1999a, 2000a).

11.5.3 Busted Butte Activities

The UZ Transport Testing planned at Busted Butte is located outside the CCAB and is sufficiently remote such that there are no waste isolation concerns.

12. IMPACT TO OTHER Q-LIST ITEMS

Any potential impacts to other Q-List (YMP 1998a) items (e.g., ESF/potential repository ground support or underground openings) are bounded by controls applied in the interest of limiting potential adverse impacts to site characterization testing (Section 10) and limiting potential impact to the waste isolation capabilities of the site (Section 11) such that additional requirements are not necessary.

13. ESTABLISHMENT OF CONTROLS

13.1 SUMMARY OF RESULTS

This evaluation concludes that various activities associated with ESF Subsurface Testing require QA controls to limit or prevent potential waste isolation or test interference impacts during subsurface testing for the YMP. Controls for these activities are presented in Section 13.3. This DIE for the ESF Subsurface Testing activities, items, and facilities described in Section 6 of this DIE is predicated on these items being temporary. Any incorporation of these items or their constituents into the preclosure or permanent repository will require a new evaluation as part of the design of permanent items.

As stated in Section 1, this evaluation applies specifically to site characterization testing activities ongoing and planned in the Subsurface ESF. The construction and operation of excavations associated with these testing activities are evaluated in the DIE for the Subsurface ESF (CRWMS M&O 1999a) and the DIE for the ECRB Cross Drift (CRWMS M&O 2000a). It should be noted that the ECRB Starter Tunnel is considered to be part of the TS Loop. Some of the discussions and controls applied by CRWMS M&O (1999a, 2000a) are repeated below for those areas where construction and testing activities overlap (e.g., water use in the ESF).

This DIE also includes an evaluation of the construction and testing at Busted Butte. While it is not specifically a Subsurface ESF test, the potential construction-to-test and test-to-test interferences are evaluated herein and an appropriate QA requirement is applied to control the activities in this short, near-surface drift.

The intent of the QA requirements in Section 13.3 is to control testing activities not specifically controlled by the Subsurface ESF DIE (CRWMS M&O 1999a). Several of the QA requirements in Section 13.3 reiterate or impose existing controls from the Subsurface ESF DIE (CRWMS M&O 1999a). Duplicate reporting or documentation is not required to meet these reiterated or imposed existing controls when construction and testing activities overlap.

Per NLP-2-0, this DIE considers the relevance of applicable requirements from the ESFDR (YMP 1997a) pursuant to ensuring that 10 CFR 60 Section 15(c)1 mandates are satisfied. The following ESFDR cites, including their lower-tier subsection requirements, were considered in this evaluation:

> ESFDR 3.2.1.1.1, 3.2.1.1.2.4, 3.2.1.1.3.1, 3.2.1.1.3.2, 3.2.1.1.3.4, 3.2.1.1.4, 3.2.1.2.3, 3.4.5.3.1, 3.4.5.6.1, 3.7.1.2, 3.7.2.1.2, 3.7.2.5.1, 3.7.3.1, 3.8.2.6.1, 3.8.2, 3.8.3, and 3.8.4

Based on the following discussions in Section 13.2, DIE-specified QA control requirements are necessary to satisfy every requirement considered by this evaluation. However, each QA control derived in Section 13.3 cites the specific, applicable requirement from YMP (1997a).

13.2 DISCUSSION/BASIS FOR CONTROLS

13.2.1 Records

It is judged that the recordkeeping provisions of 10 CFR 60.72 as applied to the ESF through ESFDR Sections 3.2.1.1.1.A, 3.2.1.1.4.C, and 3.7.1.2.B (YMP 1997a) also provide a function of limiting impact in accordance with 10 CFR 60.15(c)(1) (e.g., information on locations and descriptions of boreholes or other testing accommodations not address by construction records) and are therefore required as QA records (Requirement 1).

13.2.2 Tracers

Section 10 indicates that release of untraced water into the tunnel represents a potential test interference item. The delivery of properly traced water is the critical consideration to providing assurance of the ability to differentiate such water from naturally occurring sources. The only approved tracer for water is LiBr. The concentration of the LiBr tracer shall be checked to be 20 ppm ± 10 ppm (Requirement 3 of CRWMS M&O 1999a). Tracer is not required in water outside the TS Loop used in mixing concrete, grout, and shotcrete (Elkins 1994a). Water taken from the existing (construction) water supply system for testing purposes is required to meet the controls in Requirement 3 of CRWMS M&O (1999a) and Requirement 2 of CRWMS M&O (2000a). Since water for testing purposes may be transported into the TS Loop and ECRB Cross Drift from sources other than the existing (construction) water supply system, it is conservatively judged that a requirement shall be implemented as a QA control to ensure that the controls of Requirement 3 of CRWMS M&O (1999a) are met for testing water (Requirement 2). As a measure applied to support appropriate interpretation of potential site characterization results, this requirement is conservatively judged to be a QA requirement for water transported into the TS Loop and ECRB Cross Drift for testing purposes.

The use of LiBr tracer in significantly higher concentrations than the above concentration is discussed in Section 6 and evaluated in Sections 10.6.1.1 and 11.3.7.4. These proposed uses have been coordinated with the PI(s) responsible for bromide-sensitive site evaluation testing by the TCO to minimize potential adverse impacts. Potential test interferences are taken into account by the responsible PI(s) when tests are fielded via integration of FWPs. Waste isolation impacts are acceptable provided the quantities do not exceed those discussed in Section 11.3.7.4.

Requirements 11 and 16 require additional SA DIE team evaluation if the proposed quantities of LiBr will be exceeded. No other QA controls are required.

The use of tracers in specific testing activities (e.g., alcoves, niches, slot cuts) are evaluated in the Section 13 discussions that apply to those specific activities. The Attachment II TFM lists identifies TFMs approved for general use (Groups 1 and 2) with special restrictions noted and includes additional groups identifying TFMs approved for use in specific testing activities. QA controls are identified in the Section 13 discussions that apply to those specific activities, if applicable.

13.2.3 Excavation of Support Areas

The use of mechanical and drill-and-blast excavation techniques to construct support areas (e.g., alcoves, niches) is bounded by requirements discussed in the Subsurface DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). Any subsurface excavation needed for testing is considered as a construction activity and is therefore allocated to the Subsurface ESF DIE (CRWMS M&O 1999a) or the ECRB Cross Drift DIE (CRWMS M&O 2000a), as appropriate, unless specifically evaluated herein. As such, it is judged that no additional QA controls are required.

13.2.4 Damage to Rock from Excavation

Per Section 11.4, damage to the rock from mechanical excavation is not expected to be significant enough to create preferential pathways during TS Loop and ECRB Cross Drift construction, including testing areas. Mechanical excavation associated with subsurface testing is expected to provide relatively low impact to the site and, as controlled by CRWMS M&O (1999a, 2000a), will limit adverse impacts to the extent practical. As such, it is judged that no additional QA controls are required.

13.2.5 Boreholes and Preferential Pathways

Per Section 11.4.2, the potential creation of preferential pathways due to borehole testing is not considered significant. The length and diameter of the boreholes are insignificant relative to the size of the tunnel excavation itself. The majority of the boreholes are placed in such a way that any preferential path would drain into the tunnel, alcove, or test support area. Often times the boreholes are instrumented and/or sealed such that they act to significantly block the hole that is created. However, some subsurface testing activities require the drilling of boreholes downward in locations where water can be allowed to collect in the borehole creating potentially undetected ponded water (i.e., hydraulic fracture testing and infiltration/percolation borehole testing). These specific situations that have the potential to create undetected ponded water are discussed below. It is judged, therefore, that borehole placement has no significant impact to waste isolation, unless it can create undetected ponded water. As such, it is judged that no additional QA controls are required.

13.2.6 Boreholes and Standoff Distances

13.2.6.1 Standoff Distances

Sections 10 and 11 indicate that in consideration of existing and planned boreholes, no minimum standoff distance requirement has been identified for the TS Loop or ECRB Cross Drift. Standoff distances are typically addressed in FWPs and in the PI, TCO, and CMD interactions associated with preparing and implementing a given test. Any standoff for future boreholes or associated excavations will be defined by DIEs prepared for those activities and the associated FWPs. Therefore, it is judged that no additional QA controls are required.

13.2.6.2 NRG-4/Alcove #4 Interactions

CRWMS M&O (1999a) and Section 10 of this DIE discuss the interaction of Alcove #4 Radial Borehole Testing and NRG-4. As discussed in Section 10 of CRWMS M&O (1999a), ESF Alcove #4 was excavated in close proximity to surface borehole UE-25 NRG-4. Testing in NRG-4 is the responsibility of Nye County, Nevada (Mitchell 1995) and, therefore, does not constitute site characterization testing. Furthermore, the PIs and TCO are responsible for configuring alcoves and tests therein, and the alcove and radial borehole layout designs have been approved by the TCO (Brake 1995a; Mitchell 1995). Since radial borehole drilling essentially comprises test configuration, it is the responsibility of the PI to field his/her test in a manner that protects the validity and veracity of the test data. The construction requirements necessary to address construction-to-test interference between the Alcove #4 test activities and NRG-4 are allocated through the Subsurface ESF DIE. The slot cut activities planned at the end of Alcove #4 are at least 25 m from UE-25 NRG-4 and per Mitchell (1998h) have been coordinated with Nye County to ensure adequate standoff distance.

With respect to tracer use, Brake (1995b) indicates that both Nye County and the PI for the radial borehole drilling and testing in Alcove #4 have mutually agreed that the use of SF_6 tracer in NRG-4 will not adversely impact radial borehole testing nor will the use of SF_6 in the radial boreholes affect the NRG-4 activities. Knowledge of past use of SF_6 in both NRG-4 and the Alcove #4 radial boreholes will assure that such usage will not create the potential for unknown impact to future tests. The fact that the quantity of noble gases and Nitrogen is recorded in a similar fashion to the quantity of SF_6 will permit the impacts to ongoing and/or future testing in NRG-4 to be evaluated, thus limiting the potential for test-to-test interference. Based on these conclusions and the discussion in the Subsurface ESF DIE (CRWMS M&O 1999a), it is judged that no additional QA controls are required.

13.2.7 Wet-Drilling and Dry-Drilling of Boreholes

Section 11.4.2 evaluates the waste isolation impacts associated with both wet-drilling and dry-drilling of boreholes in the Subsurface ESF. The water used in wet-drilling is required to be reported in accordance with Requirement 3 as discussed in Sections 13.2.12 and 13.2.13. No other significant waste isolation impacts were identified for wet-drilling of boreholes. Dry-drilling of boreholes was also determined in Section 11.4.2 to have negligible waste isolation effects. The TCO coordination with the Constructor, CMD, and PIs is considered to be adequate to avoid test interferences associated with the drilling of boreholes. Future ESF testing boreholes that have not been evaluated and/or differ significantly in length and diameter from previously evaluated boreholes require additional evaluation by the SA DIE team. As such, it is judged that no additional QA controls are required.

13.2.8 Geologic Mapping

Geologic mapping activities were evaluated in the Subsurface DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). Any geologic mapping needed for testing is associated with the construction activity and is therefore allocated to the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a), as appropriate. As such, it is judged that no additional QA controls are required.

13.2.9 Timing of Test Support Area Construction

The timing of the construction of the test alcoves is important to site characterization activities since the test alcoves are located at or near faults or key geologic contacts. The instrumentation in the test alcoves collects data that may be irretrievable if alcove construction was delayed until the entire ESF was constructed. Per CRWMS M&O (1999a, 2000a), the field-determined location and timing of construction for test support areas is subject to TCO approval. Since the timing of excavation of these test support areas is a construction activity, it is allocated to the Subsurface and ECRB Cross Drift DIEs. As such, it is judged that no additional QA controls are required.

13.2.10 Shotcrete

As required by CRWMS M&O (1999a, 2000a), the constructor must coordinate with the TCO before applying shotcrete in the test alcoves, TS Loop, and ECRB Cross Drift, to assure access for testing (Requirement 12 of CRWMS M&O 1999a and Requirement 10 of CRWMS M&O 2000a). Application of shotcrete in support of testing is considered a construction activity and is therefore allocated to the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a), as appropriate. Requirement 12 of CRWMS M&O (1999a) also applies to testing activities at Busted Butte. As such, it is judged that no additional QA controls are required.

13.2.11 Cement Grouting

Section 10.5.10 indicates that cementitious grouting pressures and quantities are to be limited, to the extent practical, for rockbolt installation to minimize impacts to the ability to properly characterize the site. CRWMS M&O (1999a) prohibits the use of cement grouted rockbolts in test support areas, to avoid altering gas sample and air permeability data, except as approved by the TCO. CRWMS M&O (2000a) restricts the use of cement grout in the ECRB Cross Drift, without TCO and/or SA DIE team approval. The use of cement grout associated with testing is considered a construction activity and is therefore allocated to the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a), as appropriate. As such, it is judged that no additional QA controls are required.

13.2.12 Water Controls

As discussed in Section 11.1, unsaturated conditions are considered an important attribute for repository performance, and lower water saturations are expected to provide better performance. CRWMS M&O (1999a) has derived the cumulative total of water loss limits for the TS Loop and associated support areas (including the ECRB Starter Tunnel). CRWMS M&O (2000a) has derived the cumulative total of water loss limits for the ECRB Cross Drift and associated support areas. Controls associated with spills of water, ponding of water, water balance and reporting requirements, and water used in cementitious materials are also included in CRWMS M&O (1999a, 2000a). CRWMS M&O (1999a, 2000a) also permit the application of location-specific water-loss limits to improve implementation. For the Alcove #5 Thermal Test, a location-specific water loss limit is provided below in Section 13.2.13. For the Alcove #8, a location-specific water loss limit is provided below in Section 13.2.46. Per CRWMS M&O (1999a, 2000a), in the absence of a location-specific DIE, any water lost during the wet-drilling of test boreholes drilled laterally or vertically from alcoves or niches shall conservatively be considered to have been lost within the footprint of the alcove or niche, and shall count against the limit for the appropriate reporting segment(s) of the alcove or niche where the borehole was drilled. The QA requirements of CRWMS M&O (1999a, 2000a) are considered adequate to control the use of water for testing such that no additional QA controls are required.

Water used in cementitious materials in alcoves (and niches) is addressed in the Subsurface ESF DIE (CRWMS M&O 1999a). CRWMS M&O (2000a) also addresses water used in cementitious materials in the ECRB Cross Drift. No additional controls on water used in cementitious materials are needed.

13.2.13 Water Controls in the TTF Drift Scale Test

Based on the evaluation of the water use in the TTF/Heated Drift (Section 11.1.4), a location-specific water loss limit is required for the TTF Heated Drift DST. The derived water loss limit uses the additional offset distance from any potential waste package emplacement locations inherent in the TTF location (i.e., a total minimum offset distance of 114 m). Additionally, the area or foot-print created by the drilling of boreholes for the DST was used to expand the available area for water to be applied. Section 11.1.4 concluded that the plan-view area for the borehole drilling pattern is approximately 1560 m^2. (Note: This area excludes the footprint of the Heated Drift itself. Water loss within the actual Heated Drift footprint--which includes the water lost during the excavation of the Heated Drift *and* water lost during the drilling of the vertical test boreholes that emanate from the Heated Drift--is treated separately, as noted in Section 11.1.4) An appropriate averaging zone was defined as a plan view-area that is about 38 m wide (transverse to the axis of the Heated Drift) and 6 m long (along the axis of the Heated Drift). The resulting total quantity of water that may be discharged in an area of 230 m^2 (i.e., approximate area of a 6 m by 38 m) is about 46,000 gallons (Requirement 3). An additional control for the TCO to coordinate with the CMD/Constructor is required to ensure that subsurface water-loss limits are not exceeded due to testing activities. This QA requirement, in addition to the application of requirements from CRWMS M&O (1999a) (discussed above in Section 13.2.12), are judged adequate to control the use of water for testing.

The location-specific water loss limit required for the TTF Heated Drift DST is predicated on an estimated vertical thickness of the dry-out zone within the Tptpln lithologic unit of less than 24 m. The definition of the dry-out zone is that the saturation falls to a level below ambient. Should this 24 m dry-out zone be exceeded, additional evaluation is required. As such, a control is deemed necessary to limit the vertical thickness of the dry-out zone to 24 m without additional SA DIE team evaluation (Requirement 4).

13.2.14 Water Controls for Alcove #10 Planned Construction and Testing

Based on the evaluation in Section 11.1.7, the amount of allowable water loss for Alcove #10 construction and testing is derived from Requirement (5e) in reference CRWMS M&O 2000a. Furthermore, controls associated with spills of water, ponding of water, water balance, reporting requirements, and water use in cementitious materials are also included in CRWMS M&O (1999a, 2000a). These QA requirements are judged adequate to control the use of water for construction and testing of Alcove #10. As such no new QA controls are required.

13.2.15 Water TFM Report and Water Balance

As discussed in CRWMS M&O (1999a, 2000a), any water not removed[4] shall be reported as a consumed quantity per the TFM Procedure (AP-2.17Q). Furthermore, the ESFDR (YMP 1997a) requires the maintenance of the capability to keep a water balance (ESFDR 3.4.5.3.1.O, 3.4.5.6.1.D, 3.8.2.6.1.A, and 3.8.2.7.1.E). QA controls applied per the discussion above are judged sufficient to limit impacts to waste isolation, to the extent practical. Water balance requirements (i.e., record of water into the tunnel; record of water going out of the tunnel; record of water used for conveyor, excavation-related dust control, and wetting of muck piles; and a listing of subsurface water uses for the report period) are allocated to and adequately addressed by CRWMS M&O (1999a, 2000a).

13.2.16 Ponding of Water

Significant ponding will lead to further limitation of the amount of water available for use, and should therefore be prevented. Any ponded water will be removed, to the extent practical, with standard pumping equipment, and any water not removed will be reported as a consumed quantity per the TFM Procedure (AP-2.17Q). Contractor spill control procedures are discussed in the Subsurface DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a) and appropriate ponding control QA requirements are provided therein. The TCO must coordinate with Constructor and CMD to ensure that testing activities do not result in ponding of water. As such, Requirement 3 imposes Requirement 7 of CRWMS M&O (1999a) and Requirement 5 of CRWMS M&O (2000a), as appropriate, as a conservative method to limit impacts to waste isolation.

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[4] As discussed in Section 13.1.16 of CRWMS M&O (1999a), water sprayed on the invert top surfaces in the TS Loop, subject to certain, stated limitations, evaporates and therefore may be considered to be "removed." In addition, some of the water used in ventilation scrubber units in the exhaust ducts from alcoves evaporates, and therefore may be considered to be "removed."

13.2.17 Water Minimization and Heater Tests

As discussed in Section 10.5.1.3, normal water usage in the vicinity of the TTF does not present a particular test interference concern. The controls on water ponding and spillage, water lost limits, and water TFM reports are judged sufficient to minimize potential impact on the heater testing such that additional QA requirements are not necessary.

13.2.18 Organics

CRWMS M&O (1999a, 2000a) have evaluated organics retained in the Subsurface ESF with respect to waste isolation. The conclusion was that organic use in the ESF shall be minimized, to the extent practical. Organics introduced via Subsurface ESF testing are also required to meet the same requirements. As such, the imposition of the QA requirements from CRWMS M&O (1999a, 2000a) for minimizing the amount of organics permanently retained, to the extent practical, are judged to be necessary (Requirement 5). Any organics that are spilled (subject to the discussion below in Section 13.2.18 for spills on inverts) or that are permanently retained in TS Loop or ECRB Cross Drift excavations shall be reported in accordance with the TFM Procedure (AP-2.17Q) (Requirement 6). Any possible effects on waste isolation due to the total amount of organics retained in the TS Loop, ECRB Cross Drift, and associated excavations will be evaluated after ESF testing is concluded per the TSPA. The above controls are sufficient to limit impacts to waste isolation and minimize potential test interference impacts.

13.2.19 Invert Spills

Per CRWMS M&O (1999a), most spills in the TS Loop should be largely mitigated by the concrete inverts and seals and liquid spills on the invert segments that are absorbed by the invert segments need not be removed. CRWMS M&O (2000a) addresses spills in the ECRB Cross Drift. Any spills resulting from testing activities will require actions similar to those describe in CRWMS M&O (1999a) for the TS Loop and in CRWMS M&O (2000a) for the ECRB Cross Drift. As such, it is judged that no additional QA controls are required.

13.2.20 Perched-Water and Inverts

As discussed in CRWMS M&O (1999a, 2000a), invert segment removal or the installation of observation ports in the inverts of the TS Loop and ECRB Cross Drift (as necessary) are acceptable mechanisms for minimizing potential test interference impacts from accumulation of fluids in/under the inverts. In accordance with Section 10 and ESFDR (YMP 1997a) Requirement B.8.3.A.2, encountering perched-water requires TCO notification to give the TCO or PI the opportunity to determine whether such measures are necessary (Requirement 13 of CRWMS M&O 1999a). After conducting tests or collecting water samples as mandated by the PIs/TCO, the remaining perched-water is to be removed in accordance with the requirements of CRWMS M&O (1999a). The QA requirements of CRWMS M&O (1999a, 2000a) are judged adequate to address perched-water removal under inverts. As such, it is judged that no additional QA controls are required.

13.2.21 TFM Control

As a conservative measure, it has been determined that the recording of consumed quantities of TFMs as QA records shall be implemented, since these reports provide additional bases for TSPA and allow verification of consumed quantities. As a result, and except as specifically exempted below, any TFMs that are permanently emplaced/committed (i.e., to remain after closure of the potential repository) to the TS Loop, ECRB Cross Drift, or associated alcoves and refuge chambers, including water, hydraulic fluid, fuel, wood, etc., must be reported in accordance with the TFM Procedure (AP-2.17Q). These reports must be controlled as QA records (Requirement 6). This control is conservatively imposed as a QA requirement to limit potential impacts to waste isolation and site characterization activities. The TCO is responsible for coordinating with the Constructor/CMD to ensure that duplicate reporting of testing TFMs does not occur.

Per Section 11.2, certain materials due to their minimal penetration into the rock matrix (e.g., filler foams, epoxies, adhesives) may be used in the ESF provided they are removed, to the extent practical, as noted in Attachment II (i.e., removed by chipping, overcoring, or similar activity).

The use of the non-organic tracer gases SF_6, Nitrogen, and nobles gases (i.e., Helium, Neon, Argon, Krypton, and Xenon) in the Subsurface ESF is exempted from reporting as a TFM, based on the expected (1) negligible impact that this gas presents to the waste isolation capabilities of a potential repository at Yucca Mountain (as discussed in Section 11.3.1 of this DIE), and (2) alternative availability of SF_6, Nitrogen, and noble gas usage records (e.g., as part of test documentation records). (Note: SUVA-COLD MP® is not included in this list of exempted tracer gases.)

13.2.22 Underground Storage Vessels

Underground storage vessels have been evaluated in CRWMS M&O (1999a, 2000a). No additional underground storage vessels (i.e., beyond the size of on-board vehicle tanks) related specifically to testing activities have been identified. Underground storage vessels are therefore allocated to and controlled by the requirements of the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). As such, it is judged that no additional QA controls are required.

13.2.23 Fires

Fires and extinguishing agents have been evaluated in CRWMS M&O (1999a, 2000a). In addition to those extinguishing agents, a fire suppression vapor (FM-200®) is to be used in Alcove #5 as a fire suppression agent. The Engineer and Architect Specifications (Fike Protection Systems 1996) and MSDS (Great Lakes Chemical Corporation 1997) for FM-200® indicate that is dispensed into the environment as a colorless, electrically non conductive vapor. Furthermore, FM-200® leaves little residue (less than 0.1 percent by volume), is expected to be contained primarily internal to the small office building at the end of the AOD, and is expected to be almost completely removed by ESF ventilation systems. Based on these qualities and no identified waste isolation or test interference concerns, FM-200® is an acceptable extinguishing agent for Alcove #5. The small quantity of soluble residue listed in Fike Protection Systems (1996) should be treated as a spill and cleaned up to the maximum extent practical. The application of water in combination with FM-200® should be minimized until the soluble residue is cleaned up.

Per CRWMS M&O (1999a, 2000a), chemical releases as a result of fires, or the extinguishment of fires, are insignificant relative to this limit (and are therefore not likely to impact waste isolation) since dry chemical residue will be removed following discharge. Any actuation of dry chemical fire protection systems or the backup use of water will be evaluated following removal of the powder and/or water, to the extent practical. The requirements associated with mitigation and reporting of spills in CRWMS M&O (1999a, 2000a) are adequate to control this activity in relation to testing. Fires and extinguishing agent are therefore allocated to and controlled by the requirements of the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). As such, it is judged that no additional QA controls are required.

13.2.24 Traced Water and Perched-Water

Section 10.6.1.1 recommends that grout used in the vicinity of perched-water testing be required to contain a tracer. Since the only available supply of nonpotable water in the TS Loop and ECRB Cross Drift is traced water (see discussion above) and grout is mixed at or near the use location, it is judged that no additional QA controls are required.

13.2.25 Rock Drills

The use of rock drills has been evaluated in the Subsurface ESF DIE (CRWMS M&O 1999a) and the ECRB Cross Drift DIE (CRWMS M&O 2000a). The use and maintenance of this and similar equipment has been allocated to CRWMS M&O (1999a, 2000a), as appropriate. As such, it is judged that no additional QA controls are required.

13.2.26 Drinking Water

Drinking water within the tunnel, alcoves, and refuge chambers has been evaluated in the Subsurface ESF DIE (CRWMS M&O 1999a). The ECRB Cross Drift DIE (CRWMS M&O 2000a) addresses the use of drinking water in the ECRB Cross Drift and associated support areas. The conclusions of CRWMS M&O (1999a, 2000a) are adequate to address any drinking water concerns associated with testing activities. (See additional chloride related discussion in Section 13.2.27 below.)

13.2.27 Chlorides

The use of chlorides is to be limited to avoid potential test interference impact (see Section 10.6.1.3) as follows: only non-chloride based ground enhancing material (e.g., GEM®) is to be used, and the use of chloride-based concrete and grout accelerators is to be limited, to the extent practical (CRWMS M&O 1999a, 2000a). TCO concurrence before such uses is judged sufficient to provide this control. The use of chloride-based tracers in selected locations (i.e., niches, slot cuts, and Alcove #1) is discussed in Section 10.6.1.3 and also requires TCO concurrence. The amount used shall be recorded in accordance with TFM reporting requirements (Requirement 8) if permanently emplaced/committed. This control is conservatively applied as a QA requirement to limit test interference impacts.

As discussed in CRWMS M&O (1999a, 2000a), the use of chlorinated water/ice for drinking and hand washing purposes in the Subsurface ESF does not present a significant test interference concern and therefore does not warrant additional QA controls. Incidental losses as a result of such uses need not be reported in accordance with TFM reporting requirements.

13.2.28 Construction Water and Sampling

Section 10.5.1.1 recommends that no water or tracers, except for the traced water used in construction and in the air-mist used to clean the tunnel walls, are to be used in the vicinity of sampling locations. Since all nonpotable water piped or transported underground is required to be traced (Requirement 3) with the only approved tracer (i.e., LiBr), no additional QA controls are required.

13.2.29 Diesel Usage and Waste Isolation

Diesel usage has been evaluated in the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). Since no testing specific diesel usage is anticipated, diesel usage has been allocated to CRWMS M&O (1999a, 2000a), as appropriate. As such, no additional QA controls are required.

13.2.30 Diesel Usage and Test Interference

Section 10 also identifies potential test interference impact on *in situ* gas testing activities due to the carbon content of diesel exhaust in the potential repository emplacement areas. Diesel usage has been evaluated in the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). Since no testing specific diesel usage is anticipated, diesel usage has been allocated to CRWMS M&O (1999a, 2000a), as appropriate. As such, no additional QA controls are required.

13.2.31 Moisture Studies Boreholes, Coreholes, Monitoring Stations, and Drip Trays

As discussed in Section 13.2.5, the boreholes and/or coreholes drilled in support of moisture studies activities are not expected to create significant preferential pathways. The moisture studies FWP (YMP 2000c) describes the PI selection and location process for boreholes, including coordination with the TCO. Drip trays may be hung from the crown of the tunnel/alcoves to collect water influx as discussed in Section 6.10.1. Per CRWMS M&O (1996a), as implemented in Section 3.01K of CRWMS M&O (1999b), appurtenances are constructed/installed such that they do not compromise the critical characteristics of the permanent function ground support system. Monitoring stations are typically stand-alone and non-intrusive such that they are unlikely to create interferences with other activities. Furthermore, construction and testing activities are unlikely to impact monitoring stations in a way that results in the corruption of the data collected. Based on these evaluations, there is minimal potential for test interference and waste isolation impacts. As such, no additional QA controls are required.

13.2.32 Seismic and Strain Monitoring in the Subsurface ESF

The Subsurface ESF portion of the seismic monitoring activities include the installation of a geophone network along the right rib of the TS Loop (and potentially in the ECRB Cross Drift) and Strong Motion Sensors (i.e., greater than 0.2 g), but may be upgraded with more sensitive equipment capable of detecting motions down to 0.005 g. The normal foot traffic, locomotives, construction vehicles/equipment, and mechanical excavators in the area are typically filtered out by the data collecting system (i.e., true seismic activities have distinctly different signatures from typical construction activities) (Smith 1997). Furthermore, the activities ongoing in Subsurface ESF alcoves do not include any anticipated excavation activities which could significantly influence the ongoing seismic monitoring. As noted in Section 6.7, the installation of the geophone network along the TS Loop right rib includes the drilling of small vertical down holes. These holes are approximately one meter above the invert and are filled with the instruments and cement such that they are unlikely to become potential preferential pathways for water. The Subsurface DIE (CRWMS M&O 1999a) discusses the impacts of drill-and-blast activities on seismic monitoring and applies appropriate controls. However, in some instances blasting may be used to induce seismic waves to evaluate seismic monitoring instrumentation and setups. Since this is a testing activity that is not necessarily a drill-and-blast activities (i.e., construction related drill-and-blast activities are allocated to the CRWMS M&O 1999a), a QA control is required for recording of the date, time, location, amount of explosive in each blasting charge, and sequencing of blasts to ensure potential test interference in minimized (Requirement 7).

As noted in Section 11.2, the blasting residue in the active seismic mapping boreholes can't be assumed to be entirely removed from the Subsurface ESF. As such, post-blast sampling or analysis of these boreholes will be required to determine the amount of residues remaining in the Subsurface ESF (Requirement 7). Based on these samples (or estimates) and further SA DIE team evaluation, overcoring of these active seismic mapping boreholes to remove the blast residue may be required before repository operations.

As noted in Section 6.9.4, a long-term strain-monitoring device is planned for installation in the TS South Ramp. Potential waste isolation impacts are associated with the use of TFMs and the drilling of small diameter boreholes. The TFMs planned to be used are consistent with those approved for use in Attachment II. The drilling of boreholes is evaluated in Sections 13.2.5 and 13.2.7, however, the boreholes planned for the strain-monitoring activity will be drilled with a downward angle, such that they could unknowingly allow for ponded water to collect. As noted in YMP (1999c), these boreholes were collared at least one meter above the tunnel invert and a borehole casing will be grouted into the boreholes. The combination of these factors and the fact that water is unlikely to pond in large quantities in that section of the TS Loop minimize any potential waste isolation impacts associated with these downward drill boreholes. Section 10.5.1.2 did not identify any test interference impacts and specifically stated that the strain-monitoring device would be of a robust enough design so as to require no special protection from normal construction activities. Furthermore, Section 10.5.1.2 states that the strain-monitoring activities will be sited so as to minimize any test-to-test interferences. As such, no additional QA controls are required for the strain-monitoring activities in the TS South Ramp.

13.2.33 Electromagnetic Interference

Per Section 10.5.6, electrical equipment, transformers, cabling, etc. associated with underground power distribution and lighting systems have the potential to influence test equipment as a result of EMI. The PIs responsible for individual testing activities will coordinate with the A/E to determine if electromagnetic protection is required. Per Section 10.5.6, EMI shielding or other mitigation may be implemented, as required, under the controls of the applicable FWP. Therefore, no additional QA controls are required.

13.2.34 Construction and Testing Utilities

Construction utilities are evaluated in the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a). Any utilities that are required for testing will be allocated to the Construction Utilities discussion of CRWMS M&O (1999a, 2000a), as appropriate. As such, no additional QA controls are required.

13.2.35 Compressed Air

ESFDR 3.8.2.8.1.D (YMP 1997a) indicates that compressed air used underground during construction and operation shall be provided with chemical tracer only upon request by the TCO. As discussed in Section 10.6.1.1, the TCO may request that traced compressed air be used; e.g., to drill core holes and for field experiments and testing in the TS Loop and associated alcoves. As such, no additional QA controls are required.

13.2.36 Compressed Air for Testing

Section 10.5.3 indicates that compressed air used for testing may need to be free of condensate. Section 6.16 of the Subsurface ESF DIE (CRWMS M&O 1999a) discusses the fact that drying, filtering, and tracing may be performed with portable units local to such tests. As stated in Section 10.5.3, additional conditioning of compressed air for testing can be addressed in the implementing FWP. Furthermore, the subsurface compressed air system is considered as a construction utility and as such is allocated to the Subsurface ESF DIE (CRWMS M&O 1999a) or ECRB Cross Drift DIE (CRWMS M&O 2000a), as appropriate. Therefore, no QA controls are required. Any test-site specific compressed air testing requirements are evaluated in the applicable FWP and/or its associated DIE.

13.2.37 Hydraulic Fracture, Goodman Jack, and Infiltration/Percolation Monitoring Boreholes

The hydraulic fracture borehole, Goodman Jack, and infiltration/percolation monitoring borehole activities involve the drilling of downward (near vertical) boreholes in the invert of the ESF. The locations selected are, by design, generally near low points in the ESF/invert. As such a control is required to minimize the long-term introduction of water into these boreholes (Requirement 9). In addition, several other downward sloping boreholes on the invert of subsurface excavations will require the same protection upon completion of the subject testing activities. The eleven downward boreholes drilled through the concrete liner in the heated drift are not expected to have the same potential to act as hidden ponding location since the concrete liner acts as a protective barrier from water entering these holes. These eleven heated drift downward boreholes are specifically exempted from Requirement 9 unless the concrete liner is removed.

13.2.38 Dry Ground Support in the Vicinity of Fault Zones

Encountering two strands of the GDF in Alcove #7 presents the opportunity to conduct testing at both locations. As such, certain precautions to mitigate potential test interference concerns as excavation in Alcove #7 continues through the Western GDF strand. Hollins (1997c) provides guidance for mitigating these concerns. The TCO expressed a concern about the use of ground support during excavation activities in Alcove #6 in the vicinity of the GDF. However, the need for dry ground support at that location was not elevated to a formal test interference concern, and no DIE was requested at that time. The Alcove #6 concern was handled with a letter from the CMD to the Constructor, which required the use of dry ground support in the vicinity of the fault. (McDonald 1997)

In addition to Alcoves #6 and #7, there may be other future situations where the use of dry ground support is warranted to limit potential test interference impacts due to additional water introduced into the rock. Therefore, the scope of this DIE extends to the more general situation in which the TCO identifies particular exclusion zones in the Subsurface ESF where water, introduced by the installation of ground support, could potentially interfere with ongoing or planned site characterization testing. As a result, holes drilled for testing, ground support, and utility installation purposes, as applicable, in the vicinity of TCO-identified exclusion zones shall be dry-drilled (Requirement 10). Dry-drilling techniques have been evaluated above in Section 13.2.7. The use of Swellex type rockbolts is also prohibited (due to the potential water loss associated with their installation) in the vicinity of TCO-identified exclusion zones (Requirement 10). These prohibitions are directly related to the test interference consideration that these types of ground support potentially add significant amounts of "avoidable" water to the testing environment associated with these fault zones. Therefore, recognizing the potential test interference concerns and also acknowledging that permanent function ground support must eventually be installed in these fault zones, a location-specific ground support requirement is considered to be warranted.

The identification of these small sections of the ESF tunnel, alcoves, niches, or other testing areas where the use of dry-drilling and dry ground support are required is incumbent on the TCO. The TCO must identify these zones before the drilling and installation of ground support to ensure that the site-specific DIE control can be implemented. The TCO may choose to apply one portion of this control and not the other (i.e., dry-drilling required, but Swellex type rockbolts allowed; or wet-drilling allowed, but Swellex type rockbolts prohibited), so long as this choice is clearly identified in TCO communication.

The use of cementitious material (e.g., grout and shotcrete) for rockbolt installation in test support areas has been evaluated in Sections 13.2.10 and 13.2.11 as being a construction-related activity that is allocated to the Subsurface ESF DIE (CRWMS M&O 1999a), which prohibits its use without TCO approval (Requirement 12 of CRWMS M&O 1999a). The use of compressed air during the dry-drilling of holes similar to those used for rockbolts has been evaluated in Section 13.2.35 and was found to not require the use of a tracer, such as SF_6, unless specifically requested by the TCO.

13.2.39 Alcove #2 Exhibit Area

Per Ricketts (1997), the ongoing testing in Alcove #2 involves packer systems emplaced in nominally horizontal boreholes near the end of the Alcove. No new drilling or instrument emplacement activities are planned by the scientific community. Ricketts (1997) further states that a science and exhibit area would not interfere with future scientific activities and would be designed to minimize interference with the ongoing scientific activities, which consist of taking instrument readouts on a periodic basis. Furthermore, an exclusion area has been defined and will be physically constructed to protect the ongoing scientific activities from visitor interference. As such, no additional QA controls are required.

13.2.40 Temporary Testing Bulkheads

The addition of Temporary Testing Bulkheads in the ESF, as discussed in Section 6.17, is a testing activity requested by the PI and coordinated with the CMD by the TCO. Section 10 identified no test interference concerns associated with the installation of the bulkheads. The bulkheads are temporary testing facilities and have no impacts on waste isolation capabilities of the site. The bulkheads will only be installed at test sites coordinated by the CMD, TCO, and appropriate PIs. The materials and sealing methods will also be coordinated by the CMD, TCO, and appropriate PIs. The TFMs used for construction and sealing of the bulkheads are included in Attachment II of this DIE. Therefore, no additional QA controls are required.

13.2.41 TS Loop Niches

Except for location-specific considerations (as noted in the following paragraphs), the design, construction, and testing methods to be used for these niches are sufficiently similar to those which were previously evaluated in CRWMS M&O (1999a) so as to be bounded by that evaluation for the construction of the niches. As such the excavation of these niches is allocated to and controlled by the Subsurface DIE (CRWMS M&O 1999a). The previous discussion of construction specific activities and associated controls related to TS Loop Niches has been incorporated into CRWMS M&O (1999a) and, as such, been eliminated from this DIE.

As a similar potential repository design consideration, this DIE does <u>not</u> evaluate the potential excavation of small openings (approximately 1 to 1.5 m in diameter by 5 m deep) around testing boreholes inside the niches. Should the TCO determine that the additional excavation of these small openings is required, an additional evaluation by the SA DIE team is required before initiating this activity. However, if it is possible to determine the desired spatial characteristics of water/dye infiltration by dry-drilling additional boreholes (i.e., boreholes adjacent to and of similar length as the original testing boreholes from which core samples reveal evidence of infiltration), the TCO may direct, in writing, that additional boreholes (which meet the same characteristics as described and evaluated above) be dry-drilled. The construction and testing activities associated with these potential, additional boreholes are bounded by the requirements and conclusions of this evaluation and CRWMS M&O (1999a).

With specific regard to the design and construction of these niches, there are three location-specific DIE Requirements for minimization of potential impacts to waste isolation and/or test interference. The niche-related testing activities was designed to measure moisture flux. Therefore, construction water use could potentially impact the results of these testing activities. Based on the criteria cited in Hollins and Mitchell (1997), location-specific controls on the use of construction water are required to minimize potential test interferences (i.e., interferences with niche testing) due to construction activities. However, except for the location-specific DIE Requirements discussed below, CRWMS M&O (1999a) requirements and conclusions sufficiently bound the potential waste isolation and test interference impacts associated with the planned construction activities for these niches.

Due to the sensitivity of these tests to additional moisture, the excavation of niches was required to be performed using mechanical excavation equipment only, and the use of construction water -- including water for geologic mapping, if applicable -- associated with these niches required monitoring by the TCO (Requirement 19c of CRWMS M&O 1999a). To ensure that the site waste isolation characteristics associated with water use was not compromised, the total amount of water which may be committed in each niche is limited to 19.5 m^3 or 5,150 gallons (Requirement 19c of CRWMS M&O 1999a), as calculated using Requirement 7e of CRWMS M&O (1999a). Section 13.2.44 imposes an additional constraint associated with water loss in Niche #3, such that it be accounted for in determining the water loss limit in Alcove #8, due to the physical proximity of the two excavations. The approximately 126 liters (about 33.3 gallons) of dyed testing water used for Niche #1; the approximately 28 liters (about 7.4 gallons) of dyed testing water used for Niche #2; and the approximately 90 liters (about 23.8 gallons) of dyed testing water for Niches #3 and #4 shall also be counted against the total committed water limit for each niche (Requirement 19c of CRWMS M&O 1999a).

Boreholes associated with these niches (for testing, ground support, and utility installation purposes, as applicable) shall be dry-drilled (Requirement 19d of CRWMS M&O 1999a). Dry-drilling techniques have been previously evaluated in Sections 11.4.2 and 13.2.7.

The use of shotcrete for sealing the niche bulkheads, as described in Mitchell (1997d), could also potentially impact waste isolation or cause test interference. Since this application of shotcrete is temporary (i.e., the shotcrete will be removed along with tunnel muck when the associated emplacement drift "turnouts" are excavated), the waste isolation impact of the shotcrete material is minimized. However, any excess water in the shotcrete mixture could potentially impact the testing in the niches. To limit this potential test interference impact, Mitchell (1997d) requires that water used to mix this shotcrete is to be minimized. Controlling the amount of water used in shotcrete under Requirement 12 of CRWMS M&O (1999a) is expected to sufficiently limit potential test interference to the extent practical.

The physical proximity of the niches to other test sites (e.g., alcoves, radial boreholes, and surface boreholes) presents a potential for test interference concerns. Per CRWMS M&O (1999a), the three nearest alcoves are the TTF, NGDFA, and SGDFA. The TTF is located on the left rib of the TS Main Drift at approximately Station 28+27 m. The NGDFA is located on the left rib of the TS Main Drift at approximately Station 37+37 m. The SGDFA is located on the left rib of the TS Main Drift at approximately Station 50+64 m. Subsequent, subsurface excavations in the vicinity of the TS Loop niches included the ECRB Cross Drift, which crosses the TS Main Drift near Station 31+60 m, and ECRB Alcove #8, which was purposefully mined directly above Niche #3 with a 20 to 30 m vertical offset. The distances between each of these subsurface activities (including the extent of their radial boreholes) and any of the planned niches are considered sufficient to conclude that the excavation activities associated with the niches will present negligible potential for impacting site characterization testing in these other activities and vice versa. (Note additionally that, in accordance with CRWMS M&O (1999a), it is the responsibility of the TCO to site subsurface test area locations--including that for these niches--so as to minimize the potential for impacting testing at other locations.) Therefore, no additional DIE-generated QA controls are required to ensure that testing activities in other Subsurface ESF alcoves are not impacted.

YMP (1997f) identifies several surface boreholes in the general vicinity (i.e., ranging between approximately 300 and 400 m) of these niches: USW UZ-N24, USW UZ-N31, USW UZ-N32, USW UZ-N35, USW UZ-N42, USW UZ-N48, USW UZ-N49, USW UZ-N98, USW G-4, USW UZ-7a, USW UZ-8, USW SD-9, USW SD-12, and USW WT-2. Per CRWMS M&O (2000b), USW UZ-8, USW UZ-N24, USW UZ-N31, USW UZ-N32, USW UZ-N35, USW UZ-N42, USW UZ-N48, USW UZ-N49, USW UZ-N98 are all less than 100 feet deep, with USW UZ-N35 (approximately 180 feet in depth), USW UZ-N31 (approximately 190 feet in depth), and USW UZ-N32 (approximately 210 feet in depth) being the deeper UZ-N boreholes. These UZ-N boreholes are relatively shallow surface boreholes that are used to characterize water infiltration processes and quantify net infiltration rates in the surficial materials. The TS Main Drift and the niches are located at a depth significantly below the maximum depths of these boreholes. The significant difference in depth (when combined with the lateral surface distance between these boreholes and the ESF niches) is considered sufficient to conclude that the activities associated with the niches will present negligible potential for impacting site characterization testing in these activities and vice versa. USW G-4, USW UZ-7a, USW SD-9, USW SD-12, and USW WT-2 are in the 750 to 4000 foot depth range (CRWMS M&O 2000b). These deeper boreholes are used to study geologic and hydrologic conditions and to monitor water levels at depths significantly below the elevation of the niches. The distance between boreholes UZ-N24, UZ-N31, UZ-N32, UZ-N35, UZ-N42, UZ-N48, UZ-N49, UZ-N98, G-4, UZ-7a, UZ-8, SD-9, SD-12, and WT-2 and the niches is considered sufficient to conclude that the activities associated with the niches will present negligible potential for impacting site characterization testing in these activities and vice versa. Therefore, no additional controls are required to ensure that surface borehole testing is not impacted.

The use of TFMs--specifically, the LiBr-traced water/aqueous dye(s) mixture(s), SF_6, and POLYCEL Expanding Foam also presents potential waste isolation and test interference concerns. An evaluation of the planned use of TFMs in an appropriate DIE is required by the TFM Procedure (AP-2.17Q). The TFMs associated with these niches, including the aqueous dyes used for niche testing (as evaluated in Section 11.3.7.3), have been evaluated in this DIE or the Subsurface ESF DIE (CRWMS M&O 1999a).

With specific regard to the aqueous dyes, Mitchell (1997a) defines the minimum concentrations required to achieve valid testing results. Section 11.3.7.3 specifically evaluates the potential impacts associated with aqueous dye concentrations and water/dye mixture volumes for the worst case niche testing (i.e., a maximum of 42 liters of food color dyed water at 10,000 ppm [about 10 grams per liter] and a maximum of 84 liters of fluorescent dyed water at 2,000 ppm [about 2 grams per liter]). Section 11.3.7.3, which is based on the CRWMS M&O (1999a) committed organic material limit, concludes that the resultant quantity of committed organics associated with these dye concentrations could potentially contribute to some undefined impact on the closest, potential waste package and that such an impact would decrease proportionate to the distance from the dye injection location.

Section 11.3.7.4 evaluates the use of Fluorine, organics, and non-Fluorine halogens in Niche #2. This evaluation was in response to the request discussed in Section 6.10.2 and Mitchell (1998b). Section 11.3.7.4 developed specific limits for Niche #2 as follows: 5.7 g of Fluorine, 2 g of organics, and 12 g of non-Fluorine halogens. The quantities requested in Mitchell (1998b) include a maximum of 0.8 g of fluorinated organic tracer and 300 g of non-Fluorine halogens for use in Niche #2. The use of the fluorinated organic tracers requested in Mitchell (1998b) will only result in a maximum increase of 0.8 g of organic material use in Niche #2. When compared with the 168 g of organic material identified in Mitchell (1997a), the use of the proposed fluorinated organic tracers in Niche #2 will result in a negligible increase in the total organic material use in Niche #2.

The quantity of non-Fluorine halogens requested for use in Niche #2 exceeds the Section 11.3.7.4 recommended limit. The purpose of the proposed Niche #2 test is to determine if the tracers remain within the local, accessible environment (i.e., are likely to be recovered in a subsequent excavation activity). The selected tracers are conservative and are likely to move with the wetting front, thus providing an accurate indication of the extent of the wetting front. Information associated with wetting front movement is critical to the future approval of tracers in other niche and slot cut tracer testing (including ECRB niche, alcove, and slot cut testing). Section 11.3.7.4 concludes that the resultant quantity of committed non-Fluorine halogens associated with these tracers concentrations could potentially contribute to some undefined impact on the closest, potential waste package and that such an impact would decrease proportionate to the distance from the tracer injection location. Given these factors, use of the requested quantity (300 g) of non-Fluorine halogens is authorized for Niche #2 only. The results of the test will be evaluated to determine if additional controls or excavation are required upon the completion of testing.

Sections 11.3.7.3 and 11.3.7.4 state that these concentrations/quantities of retained tracers do not ensure that impact to waste isolation will occur and that only a relatively small area of the potential repository block could experience tracer values exceeding the above criterion. Further, there is no indication that a potential impact is not mitigable. To ensure that potential adverse impacts on the long-term potential repository are minimized to the extent practical: the amounts of aqueous dyes used in niche testing shall be limited to the maximum aqueous dye concentrations and water/dye mixture volumes identified in Mitchell (1997a); the quantity of committed Fluorine is limited to a total of 5.7 g in Niche #2; the quantity of non-Fluorine halogens is limited to a total quantity of 300 g in Niche #2; and the total quantity of Fluorine and non-Fluorine halogen traced water is limited to 20 liters in Niche #2 (Requirement 11a). Increases to tracer concentrations, tracer quantities, or water/tracer mixture volumes will require further evaluation by the SA DIE team (Requirement 11a).

The additional tracer testing at Niche #2 was designed to provide data on the movement of tracers within the niche test beds. Based on the results published in CRWMS M&O (2000c) and the discussion included in Section 11.3.7.5, tracer migration appears to be localized and possibly confined to a small area directly below the liquid-release interval. With this information, it is reasonable to assume that the tracer releases planned in the TS Loop niches will not leave the test bed prior to repository operation. If deemed necessary to remove these tracers prior to repository operation, a mineback or similar operation could be performed to remove the tracers from the repository region. In summary, it is reasonable to assume that the release of the tracers above TS Loop niches can be removed to levels below those recommended to minimize waste isolation impacts. Therefore, the release of those tracers previously not approved for use up to those quantities and concentrations identified in Mitchell (1998a) are authorized. Increases to tracer concentrations, tracer quantities, or water/tracer mixture volumes will require further evaluation by the SA DIE team (Requirement 11a).

Water use within the ESF has been previously evaluated by CRWMS M&O (1999a). Due to potential test interferences associated with niche testing, Requirements 11c, 11d, and 11e have also been established for these niches (including the calculation of a site-specific committed water limit using Requirement 7e of CRWMS M&O 1999a). Other than the site-specific water use restrictions and Requirement 7 of CRWMS M&O 1999a, no additional requirements are necessary to adequately control the water use associated with this construction/testing activity. LiBr, SF_6, and Macklanburg-Duncan POLYCEL Expanding Foam have also been previously evaluated by CRWMS M&O (1999a). CRWMS M&O (1999a) imposes no restrictions on the use of SF_6 and exempts its reporting as a TFM per the TFM Procedure (AP-2.17Q). Requirement 3 of CRWMS M&O (1999a) sufficiently controls LiBr tracer in water used in the Subsurface ESF. CRWMS M&O (1999a) also requires that POLYCEL Expanding Foam be removed upon the conclusion of testing activities. Since the niches are expected to be completely "removed" during the excavation of the "turnouts" of the potential repository emplacement drifts, no further DIE Requirements are necessary to control the use of these TFMs.

13.2.42 TS Loop Alcove Slot Cuts

Per Section 6.10.3, the alcove slot cuts are excavated by a combination of drilling and mechanical mining techniques and was allocated to and controlled by the Subsurface DIE (CRWMS M&O 1999a). The previous discussion of construction related activities and associated controls related to TS Loop alcove slot cuts have been incorporated into CRWMS M&O (1999a) and, as such, been eliminated from this DIE.

Alcove slot cut standoff distances and potential NRG-4/Alcove #4 interactions are discussed in Section 13.2.6 above. Review of CRWMS M&O (1994a) showed that the proposed slot cuts in Alcoves #4 and #6 were not located above potential WE areas. The Alcove #4 slot cut was displaced horizontally at least 100 m and vertically at least 75 m from the potential lower WE block expansion area. The Alcove #6 slot cut is down grade (at least 5 percent) for the 55 m of

Alcove #6 (resulting in at least 92 m of horizontal offset from the upper WE block) with some additional vertical displacement due to the planned positive grade for the primary WE drifts. The potential lower WE block expansion area is displaced vertically approximately 65 m below Alcove #6, and is separated horizontally by at least 100 m and the Ghost Dance Fault. The TS Loop niches are sized and located such that the majority of the test area is planned to be excavated during the construction of the potential WE drifts. No such control exists nor is needed for the specific TFMs approved for use in this DIE for the alcove slot cut test areas.

The use of tracers in alcove slot cuts is discussed in Section 11.3.7.4 and found that the limiting mass of committed (i.e., not recovered in the slot cuts) tracer elements or compounds to be 6 g of organic material, 18 g of Fluorine, and 39 g of halogens (other than Fluorine). These limits, derived for Alcove #6 are based on a 92-m offset from potential WE location and may be conservatively applied to Alcove #4 because of its greater offset from potential WE locations. As such, a QA control is required to limit the committal of tracers beyond these quantities in alcove slot cuts without further SA DIE team evaluation (Requirement 13).

13.2.43 Notification of Principal Investigator of Construction and Testing Activities

The PIs and TCO are organized within a single management organization. The TCO is tasked with coordination of construction and testing activities with the Constructor and CMD. Coordination of construction and testing activities that may impact testing results, is ensured by the coordination between the Constructor and CMD and/or implementation of controls in the FWPs developed by the TCO. As stated in Section 10.8, FWPs ensure that potential interference from and with other test activities are minimized. Therefore, no additional QA requirements are imposed for PI notification.

13.2.44 ECRB Cross Drift Moisture Flux Studies

The proposed ECRB Cross Drift moisture flux studies (excluding the "water" and "surfactant" test zones evaluated in CRWMS M&O 2000a) are sufficiently similar to other moisture flux studies evaluated herein so as to be bounded by those evaluations. The drilling of the ECRB Cross Drift moisture flux studies boreholes, including those drilled for the ECRB systematic hydrologic characterization testing, are considered to bounded by the evaluation in CRWMS M&O (2000a). Furthermore, the construction of drainage benches in the ECRB Cross Drift is sufficiently similar to other small scale construction activities so as to be bounded by CRWMS M&O (2000a). Since some of the proposed moisture flux boreholes are drill in a downward direction from near the invert of the ECRB Cross Drift, Requirement 9 is applied to limit the long-term introduction of water into these boreholes.

With respect to tracer use for the ECRB systematic hydrologic characterization testing, Section 11.3.5 establishes limits within the Phase II region of the ECRB Cross Drift. Table 11.1 in Section 11.3.5 provides recommended loss limits for DOCs, Fluorine, and other halogen-bearing salts to ensure negligible potential for waste isolation impacts from the release of these materials. The recommended limits in Table 11.1, 2.9 g/m for DOC, 8.4 g/m for Fluorine, and 17.7 g/m for other halogen-bearing salts, are applicable to any tracer releases in the ECRB systematic hydrologic characterization boreholes. Since the quantity of these tracers not subsequently recovered in drip collection systems is expected to be committed (i.e., no reasonable means exist for subsequent removal of the released tracers), the quantity of tracer loss is subject to the Table 11.1 limits. However, it is reasonable to average the tracer loss over the 10 m section of the ECRB Cross Drift in which they are release, since the released concentrations can be expected to be diluted by the time it reaches potential WE zones (i.e., tracers released in the crown of the ECRB Cross Drift don't have a direct pathway to the potential WE zones). As such, a QA control is required to limit the committal of tracers lost to the limits recommended in Table 11.1, as average over the 10 m section of the ECRB Cross Drift in which they are release without further SA DIE team evaluation (Requirement 14).

13.2.45 ECRB Niches and Alcoves

Except for location-specific considerations (as noted in the following paragraphs), the design, construction, and testing methods to be used for ECRB niches and alcoves are sufficiently similar to those which were previously evaluated in CRWMS M&O (2000a) so as to be bounded by that evaluation for the construction of the niches and alcoves. As such the excavation and construction of ECRB niches and alcoves is allocated to and controlled by the ECRB Cross Drift DIE (CRWMS M&O 2000a), as appropriate.

The physical proximity of the ECRB niches and alcoves to other test sites (e.g., other niches and alcoves, radial boreholes, and surface boreholes) presents a potential for test interference concerns. Per CRWMS M&O (1999a), the three nearest TS Loop alcoves are the TTF, NGDFA, and SGDFA and the two nearest TS Loop niches are Niches #1 and #3. The TTF is located on the left rib of the TS Main Drift at approximately Station 28+27 m. The NGDFA is located on the left rib of the TS Main Drift at approximately Station 37+37 m. The SGDFA is located on the left rib of the TS Main Drift at approximately Station 50+64 m. Niche #1 and #3 are located on the right rib of the TS Main Drift at approximate Stations 35+66 m and 31+07 m, respectively. In the ECRB Cross Drift, the Systematic Drilling boreholes and drainage bench testing are the nearest significant testing activities. The distances between each of these subsurface activities (including the extent of their radial boreholes) and any of the planned ECRB niches and alcoves are considered sufficient to conclude that the excavation and testing activities associated with the ECRB niches and alcoves will present negligible potential for impacting site characterization testing in these other activities and vice versa. (Note additionally that, in accordance with Sections 10.8 and 13.2.11 of CRWMS M&O (2000a), it is the responsibility of the TCO to site subsurface test area locations--including that for these ECRB niches and alcoves--so as to minimize the potential for impacting testing at other locations.) Therefore, no additional DIE-generated QA controls are required to ensure that testing activities in other Subsurface ESF alcoves and niches are not impacted.

CRWMS M&O (2000b) identifies several surface boreholes in the general vicinity (i.e., ranging between approximately 300 and 400 m) of the ECRB niches and alcoves: USW UZ-N24, USW UZ-N64, USW UZ-N98, USW SD-6, and USW SD-9. Per CRWMS M&O (2000b), USW UZ-N24, USW UZ-N64, and USW UZ-N98 are all less than 100 feet deep. These UZ-N boreholes are relatively shallow surface boreholes that are used to characterize water infiltration processes and quantify net infiltration rates in the surficial materials. The TS Main Drift and ECRB niches and alcoves are located at a depth significantly below the maximum depths of these boreholes.

The significant difference in depth (when combined with the lateral surface distance between these boreholes and the ECRB niches and alcoves) is considered sufficient to conclude that the activities associated with the ECRB niches and alcoves will present negligible potential for impacting site characterization testing in these boreholes. USW SD-6 and USW SD-9 depths are in the 2000 to 3000 foot depth range (CRWMS M&O 2000b). These deeper boreholes are used to study geologic and hydrologic conditions and to monitor water levels at depths significantly below the elevation of the niches. The distance between boreholes USW SD-6 and USW SD-9 and the ECRB niches and alcoves is considered sufficient to conclude that the activities associated with the ECRB niches and alcoves will present negligible potential for impacting site characterization testing in these activities and vice versa. Therefore, no additional controls are required to ensure that surface borehole testing is not impacted.

The use of shotcrete, sodium silicate, and/or cement for sealing the ECRB niches and alcoves bulkheads, as described in Mitchell (2000a) and Peters (2000), could potentially impact waste isolation or cause test interference. Since this application of shotcrete, sodium silicate, and/or cement is temporary (i.e., the shotcrete, sodium silicate, and/or cement can be removed, if deemed necessary, prior to repository operations), the waste isolation impacts of the shotcrete, sodium silicate, and/or cement material are minimized. However, any excess water in the sealing mixture could potentially impact the testing in the ECRB niches and alcoves. To limit this potential test interference impact, Mitchell (1997d) requires that water used to mix this shotcrete is to be minimized. Controlling the amount of water used in shotcrete and/or cement under Requirement 10 of CRWMS M&O (2000a) is expected to sufficiently limit potential test interference to the extent practical. Control of such activities under Requirement 10 of CRWMS M&O (2000a) is considered adequate such that no additional QA controls are required.

The testing planned in Niche #5 (and potentially in Niche #6, should it be constructed) involves injection of various tracers and water into the boreholes above the actual niche testing area. The testing is similar to that performed in the TS Main Drift niche studies and is discussed in Section 11.3.7.5. The total quantity of traced water expected to be released at Niche #5 during testing is approximately 350 gallons (Mitchell 1999b). As noted in Section 11.3.7.5, CRWMS M&O (2000c) showed tracer migration to be localized and possibly confined to a small area directly below the liquid-release interval. With this information, it is reasonable to assume that the tracer releases planned in Niche #5 (and potentially in Niche #6, should it be constructed) will not leave the test bed prior to repository operation. If deemed necessary to remove these tracers prior to repository operation, a mineback or similar operation could be performed to remove the tracers from the repository region. In summary, it is reasonable to assume that the release of the tracers above ECRB Niches can be removed to levels below those recommended to minimize waste isolation impacts. Therefore, the release of tracers up to those quantities and concentrations identified in Mitchell (1999b) are authorized. Increases to tracer concentrations, tracer quantities, or water/tracer mixture volumes will require further evaluation by the SA DIE team (Requirement 11b).

The testing planned in Alcove #8 involves the injection of a large quantity of traced water via gravity flow into the section of rock between ECRB Cross Drift Alcove #8 and TS Loop Niche #3. Drip trays should collect the water that seeps into Niche #3. This testing is similar to that performed from the ground surface into Alcove #1 as discussed in Section 13.2.46, however, a lesser quantity of water is expected to be required to establish the seepage into Niche #3 due to the higher initial rock saturation levels. The preliminary small-scale test in the back of Alcove #8 (above the TS Main Drift Niche #3 breakout point) (Wang 2001) has resulted in providing evidence that some of the Alcove #8 injected water was able to move to Niche #3 during a limited time frame. Preliminary results of water injection in Alcove 8 has recovered thus far in Niche #3 approximately 8% of the water injected into Alcove #8 over a time period of 21 days which has been used to calibrate the Pre-Test Model (BSC 2001). The model has been used to make prediction for the distribution of water after injection. The model calibration and prediction is an iterative process which will be updated during both flow and tracer application stages to improve confidence in assessment of these processes (Wang 2001). The positive slope of the Alcove #8 invert minimizes any long-term water loss concerns associated with the proposed small scale test trench described in Section 6.10.5. The use of an air block as described in Mitchell (2000a) is not expected to create any test interference or waste isolation concerns.

The final approximate 13 m of Alcove #8 overlies the entirety of Niche #3 with the main water injection test area (approximately 3 m by 4 m sand filled box) that overlies the bulkhead isolated section of Niche #3 (the last approximate 7 m of the niche). Although Alcove #8 is excavated from the Phase II portion of the ECRB Cross Drift, the end (approximately 13 m) of the alcove are near the Phase I distance from potential emplacement locations. For the water injection test area in Alcove #8 (last approximate 13 m of Alcove #8), the offset from potential emplacement locations can be shown to be approximately 30 m. The total water loss in the approximate 13 m section of Alcove #8 where the main injection test is planned shall not exceed 568.182 m^3 (approximately 150,000 gallons). This total water loss includes all water lost during construction of and testing in Alcove #8. Furthermore, since the water loss in Alcove #8 and Niche #3 will occupy the same section of rock, the total water loss for Alcove #8 must also include all water lost during construction of and testing in Niche #3 (on the order of a few hundred gallons). Thus the water loss for the final approximate 13 meters of Alcove #8 shall not exceed an average of 43.71 m^3/m (approximately 11,538.5 gal/m). It is recommended that the 10 m section of Alcove #8 where the main injection test is planned and the final approximate 3 m section of Alcove #8 where the preliminary small-scale injection test has been conducted be tracked as individual sections for TFM reporting purposes (i.e., a shorter section of Alcove may be used for TFM reporting purposes ahead of the final 13 m of Alcove #8). The remainder of Alcove #8 is subject to the Phase II water limits discussed in CRWMS M&O (2000a) (i.e., 2.5 m^3/m or approximately 640 gal/m).

Alcove #8 incorporates the drilling of several instrumented boreholes and one borehole which physically connects Alcove #8 with the TS Loop outside of Niche #3. Several of these boreholes are directed downward such that they could become potential hide ponded water. The fact that Alcove #8 has a positive slope, no permanent water supply other than testing water, and the instrumentation will occupy the majority of the boreholes, minimizes the concern with ponded water. The borehole that connects Alcove #8 with the TS Loop is physically elevated an additional 0.75 m above the alcove invert, thus further minimizing the possibility of it inadvertently becoming a pathway for water flow. Requirement 9 is conservatively applied to these downward sloped boreholes upon completion of the testing activities at Alcove #8.

13.2.46 Alcove Infiltration Testing

The application of traced water on the ground surface above Alcove #1 will exceed the 2.6 feet/year (0.48 gallons/square yards/day) evapotranspiration rate evaluated in Sections 11.1.1 and 13.2.2.1 of CRWMS M&O (1999c). In fact, the plastic sheeting placed above the water application area is designed to enhance the penetration of the water into the underlying rock. Using the conservative assumption that all the water applied will penetrate the underlying rock, the proposed Alcove #1 test results in approximately 245,000 gallons of water penetrating into the underlying rock during the initial phase of testing. Water is applied intermittently at a rate of ranging up to 8 cm (3.2 inches) per day. Per Guertal (1998), the actual application area was approximately 35 feet by 26 feet. Assuming the an additional one half foot effective wetting area on each side results in a 36 foot by 27 foot application area. Wetting of the ground surface was observed up to 16 feet downgrade from the application area, which conservatively extended the wetting area an additional 10 feet, resulting in an effective wetting area of 36 foot by 37 foot (or approximately 148 square yards). It should be noted that only about 50 percent of this application area actually overlies Alcove #1.

CRWMS M&O (1999c) has evaluated the application of water in excess of the evapotranspiration rate (with or without surface ponding) and concluded that it is unlikely to affect potential repository performance, if the cumulative excess at any point on the surface is less than 13.5 feet over the lifetime of the ESF activities (Section 11.1.1 of CRWMS M&O 1999c). CRWMS M&O (1999c) (Section 11.1.4) was revised in March 1999 to include additional information on the affects of surface water discharge east of the Bow Ridge Fault and concluded that surface water discharges of up to 29,000 gallons per day or less over a 25-year period were permissible east of the Bow Ridge Fault. As such, CRWMS M&O (1999c) concluded that for locations east of the Bow Ridge Fault, the 13.5-foot water limit no longer applied and that no water loss limit was required.[5]

Since the water application area is directly above Alcove #1 and the distance from the ground surface is relatively short (approximately 30 m), the quantity of water previously used in Alcove #1 was checked to provide assurance that the combined effects of the previously applied subsurface water and the proposed infiltration testing water will not create a problem. A review of the TFM database revealed two actual use TFM reports for water use in the ESF Starter Tunnel and Alcove #1. The quantity of water reported in TFM report numbers R-94-006 and R-94-008 (REECO 1993a, 1993b, respectively) was 453,133 gallons. Since it took several months to construct the ESF Starter Tunnel and Alcove #1, this total is clearly less than 29,000 gallons per day.

There are no TFM records showing previous applications of water in the proposed water application area. Based on the fact that the ground surface above Alcove #1 is at least 20 m offset from the drainage channel protecting the ESF North Portal and Pad and there are no Surface-Based Testing activities that have occurred in that location, it is unlikely that any significant water application would have occurred.

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[5] Due to the substantial increase in the water loss limit calculated in CRWMS M&O (1999c), the previous discussions in this section have been drastically reduced and only applicable discussions remain.

Review of Map YMP97-12-05 (YMP 1997), showed that the area in which the Alcove #1 water is applied is east of the Bow Ridge Fault. The Bow Ridge Fault intersects the TS Loop in the vicinity of Alcove #2 (the Bow Ridge Fault Alcove) approximately 200 meters west of the ESF North Portal. Since the Alcove #1 water application area is clearly east of the Bow Ridge Fault and 13.5-foot water limit that was used in CRWMS M&O (1999c) to establish the previous water loss limit is no longer applicable. Furthermore, the water application rates discussed in Guertal (1998) will not exceed 29,000 gallons per day and therefore, will have negligible waste isolation impacts. There are no other ongoing testing activities in the vicinity of Alcove #1 that would be impacted by the proposed use of water above Alcove #1.. Therefore, there are no test interference impacts associated with the water use. As such, the previous control(s) that required additional evaluation prior to exceeding the designated water loss limit is no longer required. Reporting of water and tracer use in accordance with the TFM Procedure at this location is still applicable (Requirement 6).

Mitchell (1998g) has identified several tracers (including higher concentrations of LiBr) to be added to the water applied above Alcove #1 such that transient flow times can be estimated once saturated flow conditions have been established. These tracers include Halogenated salts, organic-based fluorescent, and aqueous dyes, and the higher than previously approved concentrations of LiBr. The proposed concentrations range from a few ppm for the organic-based tracers to 500 ppm for LiBr and Calcium Bromide to 2,000 ppm for sodium chloride. The total quantity of Halogenated salts (excluding LiBr) is approximately 790 kg. The total quantity of LiBr is approximately 152 kg. The total quantity of organic-based fluorescent and aqueous dyes is approximately 7 kg.

As discussed in Section 11.3.7.4, these quantities of tracers proposed for use in Alcove #1 infiltration testing will only affect approximately 0.0125 percent of the SZ. Since the potentially affected area of the SZ is small and the approached used in Section 11.3.7.4 is quite conservative, the proposed tracers are allowable for use in Alcove #1 infiltration water. However, a QA control is required to limit the application of tracers in Alcove #1 infiltration testing beyond these quantities without further SA DIE team evaluation (Requirement 16).

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Based on the evaluation of the water use in the Alcove #8/Niche #3 testing (Section 11.1.4), a location-specific water loss limit is required for the Alcove #8/Niche #3 testing. The derived water loss limit uses the results of the Pre-Test Modeling Evaluation of Flourobenzoic Acid Tracer Transport in the Alcove 8-Niche 3 Cross-Over Test (BSC 2001). This Model indicates that injected water for this testing will migrate vertically downward with a lateral dispersion of no more than 20 m. As such the water use maximum limit for tracer testing in Alcove#8/Niche #3 is 150,000 gallons (Requirement 3c). This QA requirement, in addition to the application of requirements from CRWMS M&O (1999a) (discussed above in Section 13.2.12), are judged adequate to control the use of water for testing.

13.2.47 Busted Butte Activities

As stated in Section 11.5.3, the UZ Transport Testing planned at Busted Butte is located outside the CCAB and is sufficiently remote such that there are no waste isolation concerns. The construction of the road and pad are limited in scope and are judged unlikely to impact planned testing at Busted Butte. Assuming similar construction techniques are used in the construction of the Busted Butte drift as for the ESF, no construction-to-test interference is anticipated from excavation and ground support. Furthermore, the TCO coordination of construction and testing activities with the Constructor and CMD discussed in Section 13.2.42 will minimize potential construction-to-test interferences. The Site Atlas (DOE 1997) does not identify any testing activities in the vicinity of the planned Busted Butte test site that could be impacted by this test. However, as discussed in Section 10.7, the TFMs used in the construction and testing of the drift and test areas have the potential to influence the planned testing activities. The two areas of concern are water application and TFM use in the vicinity of test boreholes and test blocks. As such, it is conservatively judged that a QA requirement to require TCO coordination and approval of water use plans and TFM application in the Busted Butte drift is required to limit potential impacts to site characterization activities (Requirement 12). The TCO is responsible for coordinating with the Constructor/CMD to ensure that duplicate reporting of testing TFMs does not occur.

13.2.48 Other Testing Activities

Other subsurface testing activities, described in Section 6, for which test interference and waste isolation impacts were generically evaluated in accordance with NLP-2-0, but not specifically identified in Sections 10 and 11, are discussed here for completeness. Potential waste isolation impacts, for the activities described in Section 6, have been identified in Section 11 of this DIE. The TCO interface with the PIs and CMD addresses potential test interference impacts for non-intrusive activities such as Consolidated Sampling, Hydrochemistry Tests, Borehole Wireline Measurements, Construction Monitoring, as well as intrusive testing such as Radial Borehole Tests and Hydrologic Properties of Major Faults. Furthermore, the test-to-test interference concerns associated with the TTF Heated Drift DST are address by the TCO/PI/CMD coordination. As such, no additional QA controls are required. Any changes to the planned tests or new site-disturbing tests will require additional evaluation by the SA DIE team.

13.3 QA REQUIREMENTS

The following QA requirements have been identified as a result of this DIE. These controls are to be applied in addition to other conventional design practices.

Requirement 1: Records required for 10 CFR 60.72 shall be maintained as QA records.

[ESFDR 3.2.1.1.1.A, 3.2.1.1.4.C, 3.7.2.1.1.A, 3.7.1.2.B]

Requirement 2: Nonpotable water transported (i.e., not taken from the existing construction water supply system) into the TS Loop and ECRB Cross Drift for testing purposes shall meet the requirements of Requirement 3 of the Subsurface ESF DIE (CRWMS M&O 1999a).

[ESFDR 3.2.1.2.3.B, 3.4.5.3.1.G, 3.4.5.3.1.P, 3.7.2.5.1, 3.8.2.6.1.E]

Requirement 3: Water use and purposeful or accidental loss of water to the environment in the TS Loop and associated support areas (including the ECRB Starter Tunnel) shall be minimized, to the extent practical, by imposing Requirement 7 of the Subsurface ESF DIE (CRWMS M&O 1999a). Water use and purposeful or accidental loss of water to the environment in ECRB Cross Drift and associated support areas shall be minimized, to the extent practical, by imposing Requirement 5 of the ECRB Cross Drift DIE (CRWMS M&O 2000a). In addition, the following controls apply:

[ESFDR 3.2.1.1.2.4.H, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.D, 3.2.1.2.3.E, 3.4.5.3.1.O, 3.4.5.6.1.C, 3.4.5.6.1.D, 3.7.1.2.C, 3.7.2.1.2.E, 3.8.2.6.1.A, 3.8.2.6.1.H, 3.8.2.7.1.E, 3.8.2.7.1.F, 3.8.2.7.1.G]

a. A location-specific water loss limit has been established for the TTF Heated Drift such that the total water lost (i.e., unrecovered water) to the environment (specifically, the Heated Drift and its associated test bed) during DST-related activities shall not exceed 46,000 gallons per each 6 linear meter segment of Heated Drift length, without additional SA DIE team evaluation. The ESF TCO shall ensure that construction water loss reported per Requirement 7e of the Subsurface ESF DIE (CRWMS M&O 1999a) (i.e., water loss attributable to Heated Drift excavation and ground support system installation), is counted against the total water loss limit established above for the Heated Drift and its associated test bed.

b. The TCO is responsible to coordinate with the CMD/Constructor to ensure that the cumulative water-loss limits established in the Subsurface ESF DIE (CRWMS M&O 1999a) and ECRB Cross Drift DIE (CRWMS M&O 2000a) are not exceeded by the application of testing water.

c. A location-specific water loss limit has been established for the Alcove #8/Niche #3 testing such that the total water lost (i.e., unrecovered water) to the environment during tracer testing and related activities shall not exceed 150,000 gallons without additional SA DIE team evaluation.

Requirement 4: The dry-out zone around the DST shall be limited to a total vertical thickness of 24 m (regardless of the physical orientation of the dry-out zone relative to the Heated Drift location) as determined by DST instrumentation. (Note that this requirement is based on a four year heating operation.) The DST dry-out zone limit shall not be exceeded without additional SA DIE team evaluation.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.D]

Requirement 5: The amount of organic material that is to be permanently retained during testing activities shall be minimized, to the extent practical, by imposing Requirement 8 of the Subsurface ESF DIE (CRWMS M&O 1999a) and Requirement 6 of the ECRB Cross Drift DIE (CRWMS M&O 2000a).

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.E]

Requirement 6: QA records shall be made and provided in accordance with the TFM Procedure (AP-2.17Q) of all TFMs that are permanently emplaced/committed (i.e., to remain after closure of the potential repository) to the Subsurface ESF and associated operation and test support areas (including Buste Butte and above Alcove #1), including water, wood, etc., and unrecovered spills, except as specifically exempted in this DIE (e.g., see Section 13.2.20).

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.E, 3.4.5.3.1.G]

Requirement 7: Minimize potential impacts on construction, testing, and other ongoing seismic monitoring activities by maintaining lifetime records of blasting activities which shall include recording of the date, time, location, amount of explosive in each blasting charge, and sequencing of blasts as part of the JP or FWP records. Furthermore, post-blast sampling or analysis of the active seismic blasting boreholes is required before repository operations to ensure blast residue is below negligible impact levels.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C, 3.2.1.2.3.D, 3.2.1.2.3.G, 3.2.1.2.3.H]

Requirement 8: The use of chloride shall be limited by imposing Requirement 14 of the Subsurface ESF DIE (CRWMS M&O 1999a) and Requirement 12 of the ECRB Cross Drift DIE (CRWMS M&O 2000a).

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B]

Requirement 9: Minimize, to the extent practical, the quantity of fluids introduced into the Alcove Hydraulic Fracturing Boreholes, Moisture Flux Boreholes, Infiltration/Percolation Monitoring Boreholes, and downward sloping boreholes on the invert of subsurface excavations by providing protection against reintroduction of fluids (e.g., by using berms, collars, grouted pipes, seals) upon completion and closure of the subject activity.

[ESFDR 3.2.1.2.3.A, 3.2.1.2.3.D, 3.8.2.6.1.H, 3.8.2.7.1.F]

Requirement 10: In those areas identified by the TCO as requiring the use of dry ground support, rockbolt holes shall be dry-drilled and the use of Swellex type bolts is prohibited. The TCO is responsible for the identification and notification of areas requiring the use of dry ground support (i.e., dry-drilled rockbolt holes and prohibition of Swellex type bolts) to the CMD and A/E. The TCO may choose to apply one portion of this control and not the other (i.e., dry-drilling required, but Swellex type rockbolts allowed; or wet-drilling allowed, but Swellex type rockbolts prohibited), so long as this choice is clearly identified.

[ESFDR 3.2.1.2.3.B, 3.7.3.1.A, 3.7.3.1.G, 3.7.3.1.K, 3.8.2.1.2.A]

Requirement 11: Testing associated with testing niches in the Subsurface ESF shall be controlled by imposing the following controls:

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C]

(11a) Due to the acknowledgment that the minimum concentrations of aqueous dyes required to perform these tests will lead to retained organic masses that exceed the limits established by Section 11 of CRWMS M&O (1999a) for committed organic material, the TCO/PI shall ensure that the emplacement of committed organic substances associated testing within niches in the TS Loop is minimized, to the extent practical. Increases in either the proposed dye concentrations or the proposed traced water/dye mixture volumes (as specified in Mitchell [1997a, 1998a]) will require further evaluation by the SA DIE team. The applicable Mitchell (1997a, 1998a) limits are reiterated as follows:

(1) The maximum concentration of food color dyes in Niches #1, #2, #3, and #4 shall be 10,000 ppm (i.e., 10 grams per liter).

(2) The maximum concentration of fluorescent dyes in Niches #1 and #2 shall be 2,000 ppm (i.e., 2 grams per liter).

(3) The maximum volumes of dyed water in Niches #1 and #2 testing activities shall be 42 liters (11.1 gallons) for food color dyes and 84 liters (22.2 gallons) for fluorescent dyes.

(4) The use of fluorinated tracers (both organics and salts) in Niche #2 testing is limited to a total emplaced quantity of 5.7 grams.

(5) The use of non-Fluorine, halogenated salts in Niche #2 is limited to a total quantity of 300 grams.

(6) The maximum volume of Fluorine and non-Fluorine halogen traced water in Niche #2 shall be 20 liters (5.3 gallons).

(7) The maximum concentration of fluorescent dyes in Niches #3 and #4 shall be 2,000 ppm (i.e., 2 grams per liter).

(8) The maximum quantity of fluorescent microspheres in Niches #3 and #4 shall be 40 grams.

(9) The maximum volumes of dyed water in Niches #3 and #4 testing activities shall be 56 liters (14.8 gallons) for food color dyes and 23.1 liters (6.1 gallons) for fluorescent dyes.

(11b) Due to the acknowledgment that the minimum concentrations of aqueous dyes required to perform these tests will lead to retained organic masses that exceed the limits established by Section 11 of CRWMS M&O (2000a) for committed organic material, the TCO/PI shall ensure that the emplacement of committed organic substances associated testing within niches in the ECRB Cross Drift is minimized, to the extent practical. Increases in either the proposed tracer concentrations or the proposed water/tracer mixture volumes (as specified in Mitchell [1999b]) will require further evaluation by the SA DIE team. The applicable Mitchell (1999b) limits are reiterated as follows:

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(1) The maximum concentration of food color dyes in Niche #5 shall be 10,000 ppm (i.e., 10 grams per liter).

(2) The maximum concentration of Rhodamine B in Niche #5 shall be 900 ppm (i.e., 0.9 grams per liter).

(3) The maximum concentration of fluorescent dyes (other than Rhodamine B) in Niche #5 shall be 4,000 ppm (i.e., 4 grams per liter).

(4) The maximum concentrations of organic Fluoride compounds in Niche #5 shall be 20 ppm (i.e., 0.02 grams per liter).

(5) The maximum concentrations of Fluoride salt compounds in Niche #5 shall be 5,000 ppm (i.e., 5 grams per liter).

(6) The maximum concentrations of LiBr applied in excess of the 20 ± 10 ppm allowed for tracing of construction water in Niche #5 shall be 2,000 ppm (i.e., 2 grams per liter).

(7) The maximum concentrations of sodium chloride in Niche #5 shall be 3,000 ppm (i.e., 3 grams per liter).

(8) The maximum concentrations of non-fluorinated salts (other than LiBr and sodium chloride) in Niche #5 shall be 5,000 ppm (i.e., 5 grams per liter).

(9) The maximum volumes of traced water in Niche #5 testing activities shall be 54 liters (14.3 gallons) for food color dyes, 4.4 liters (1.2 gallons) for Rhodamine B, 27 liters (7.1 gallons) for fluorescent dyes, 350 liters (about 92.5 gallons) for organic Fluoride compounds, 30 liters (about 7.9 gallons) for Fluoride salt compounds, 105 liters (about 27.7 gallons) for non-fluorinated salts (bromides, iodides, and sodium dihydrates excluding sodium chloride and LiBr), 20 liters (about 5.3 gallons) for sodium chloride, and 20 liters (about 5.3 gallons) for LiBr in excess of the 20 ± 10 ppm allowed for tracing construction water.

(10) The use of Microspheres in Niche #5 is limited to a total quantity of 80 grams.

(11) The maximum volume of traced water used in releasing the Microspheres into the Niche #5 boreholes shall be 100 liters (about 26.4 gallons).

Requirement 12: The TCO shall approve water use plans and TFM applications in the Busted Butte drift.

[ESFDR 3.2.1.2.3.B, 3.7.3.1.A, 3.7.3.1.G, 3.7.3.1.K, 3.8.2.1.2.A]

Requirement 13: The quantity of tracers applied during TS Loop alcove slot cut testing shall not exceed the following limits without further SA DIE team evaluation:

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C]

(13a) The use of organic tracers (fluorescent dyes, food color dyes, and fluorinated organics) above 6 grams in alcove slot cuts is prohibited.

(13b) The use of fluorinated tracers (both organics and salts) is limited to a total emplaced quantity of 18 grams.

(13c) The use of non-Fluorine, halogenated salts is limited to a total emplaced quantity of 39 grams.

Requirement 14: Tracers lost (i.e., not subsequently recovered) in ECRB Systematic Drilling boreholes shall not exceed the following quantities, as averaged over the 10 m section of the ECRB Cross Drift in which they are released, without further evaluation by the SA DIE team:

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C]

(14a) The emplaced quantity of fluorinated tracers used in ECRB Systematic Drilling boreholes shall not exceed 8.4 grams per meter.

(14b) The emplaced quantity of non-Fluorine, halogenated salt tracers used in ECRB Systematic Drilling boreholes shall not exceed 17.7 grams per meter.

(14c) The emplaced quantity of non-fluorescent, organic tracers used in ECRB Systematic Drilling boreholes shall not exceed 2.9 grams per meter.

(14d) The concentration of fluorescent tracers used in ECRB Systematic Drilling boreholes shall not exceed 1 ppm (i.e., 0.001 gram per liter).

Requirement 15: The total quantity of water emplaced during ECRB Systematic Drilling boreholes shall not exceed 90 percent of the Requirement 3 water loss limit when combined with all other water losses (e.g., construction, dust control, drilling, testing) in the 10 m section of the ECRB Cross Drift in which it is used, without further evaluation by the SA DIE team.

[ESFDR 3.2.1.1.2.4.H, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.D, 3.2.1.2.3.E, 3.4.5.3.1.O, 3.4.5.6.1.C, 3.4.5.6.1.D, 3.7.1.2.C, 3.7.2.1.2.E, 3.8.2.6.1.A, 3.8.2.6.1.H, 3.8.2.7.1.E, 3.8.2.7.1.F, 3.8.2.7.1.G]

Requirement 16: The quantity of tracers applied with the Alcove #1 infiltration testing water shall not exceed the following limits without further SA DIE team evaluation:

[ESFDR 3.2.1.1.3.2.D, 3.2.1.2.3.A, 3.2.1.2.3.B, 3.2.1.2.3.C]

(16a) The total quantity of Halogenated salts (excluding LiBr) shall not exceed 790 kg.

(16b) The total quantity of LiBr applied in excess of the 20 ± 10 ppm allowed for tracing of construction water shall not exceed 152 kg.

(16c) The total quantity of organic-based fluorescent and aqueous dyes shall not exceed 7 kg.

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Requirement 17: Fluoroelastomer rubber (Viton) shall not be used in drill holes inside or near waste emplacement drifts where the hardware could be exposed to elevated temperatures higher than 100 ° C without further Safety Assurance Department evaluation.

The preceding requirements shall be documented, as appropriate, in FWPs, design analyses, specifications, drawings, and/or sketches to ensure that the requirements are adequately translated into implementing documents. Records generated as a result of the QA requirements contained in this DIE shall be maintained as lifetime QA records.

13.4 QUANTITATIVE TFM REQUIREMENTS

There are no quantitative TFM requirements specifically derived from this DIE.

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15. ATTACHMENTS

Attachment I	List of Acronyms
Attachment II	TFMs Evaluated for Use within the ESF in Support of Subsurface Testing Activities

ATTACHMENT I

LIST OF ACRONYMS

LIST OF ACRONYMS

10 CFR 60	Code of Federal Regulations, Title 10, Part 60
A/E	Architect/Engineer
AOD	Access/Observation Drift
AP	Yucca Mountain Project Administrative Procedure
CCAB	Conceptual Controlled Area Boundary
CDTT	Cross-Drift Thermal Test
CH	Calico Hills
CHn	Calico Hills Tuff nonwelded
cm	Centimeter(s)
CMD	Construction Management Department
CRWMS	Civilian Radioactive Waste Management System
DCS	Data Collection System
DIE	Determination of Importance Evaluation
DOC	Dissolved Organic Carbon
DOE	United States Department of Energy
DST	Drift Scale Test
ECRB	Enhanced Characterization of the Repository Block
EDA	Engineered Design Alternative
EMI	Electromagnetic Interference
ERT	Electrical Resistivity Tomography
ESF	Exploratory Studies Facility
ESFDR	ESF Design Requirements Document
FD&C	Federal Food, Drug, and Cosmetic Act
FWP	Field Work Package
g/m	grams per meter
g/m^2	grams per square meter
g/m^3	grams per cubic meter
GDF	Ghost Dance Fault
ICN	Interim Change Notice
kg	Kilogram(s)
LiBr	Lithium Bromide
m	Meter(s)
m^2	Square meter(s)
m^3	Cubic meter(s)
mm	Millimeter(s)

M&O	Civilian Radioactive Waste Management System Management and Operating Contractor
MPBX	Multiple-Point Borehole Extensometers
MSDS	Material Safety Data Sheet
NEPO	Natural Environment Program Operations
NGDFA	Northern Ghost Dance Fault Alcove
NLP	Nevada Line Procedure
PI	Principal Investigator
ppm	Parts Per Million
PTn	Paintbrush nonwelded
PVC	Polyvinyl Chloride
QA	Quality Assurance
SA	Safety Assurance
S&ET	Science and Engineering Testing Group of Bechtel-SAIC Company, an LLC
SS&FS	Field Services and Field Support Group of Bechtel-SAIC Compnay, an LLC
SBT	Surface-Based Testing
SGDFA	Southern Ghost Dance Fault Alcove
SF_6	Sulfur Hexafluoride
SZ	Saturated Zone
TBM	Tunnel Boring Machine
TCO	Test Coordination Office
TCw	Tiva Canyon welded
TFM	Tracers, Fluids, and Materials
TM	Thermal/Mechanical
TMA	Thermomechanical Alcove
TMHC	Thermal/Mechanical/Hydrological/Chemical
Tptpll	Topopah Spring crystal-poor, lower lithophysal
Tptpln	Topopah Spring crystal-poor, lower nonlithophysal
Tptpmn	Topopah Spring crystal-poor, middle lithophysal
Tptpul	Topopah Spring crystal-poor, upper lithophysal
Tptrv	Topopah Spring crystal-rich, vitric, non- to moderately welded
TS	Topopah Spring
TSPA	Total-System Performance Assessment
TSw	Topopah Spring welded
TSw1	Topopah Spring welded, lithophysae-rich
TSw2	Topopah Spring welded, lithophysae-poor
TSw3	Topopah Spring welded, vitrophyre
TTF	Thermal Testing Facility
UO	Undifferentiated Overburden
USGS	United States Geologic Survey

UZ	Unsaturated Zone
WE	Waste Emplacement
YMP	Yucca Mountain Site Characterization Project

ATTACHMENT II

TFMS EVALUATED FOR USE WITHIN THE ESF

IN SUPPORT OF SUBSURFACE TESTING ACTIVITIES

TFMs EVALUATED FOR USE WITHIN THE ESF IN SUPPORT OF SUBSURFACE TESTING ACTIVITIES

General Note: The TFMs listed below have been reviewed and are used to establish a TFM baseline for this evaluation. TFMs which are permanently emplaced are subject to DIE Requirement 6. TFMs listed below are exempted from the installation and removal reporting requirements of procedure AP-2.17Q, unless they are permanently emplaced or prohibited for use by this DIE.

General Note: Any TFMs containing organics that will be permanently retained are subject to DIE Requirement 5.

Group 1 **Approved for use in accordance with the manufacturer's directions and precautions relative to application, storage, disposal, etc.**

007 - Chemical Sharpener (torch tip cleaner)
Aervoe-Pacific Marking Paint
Aluminum
American Polywater SpliceMaster Cable Cleaner Type GX
Argon (Noble Gas)
Austin Powder Company - Detonating Cord
Austin Powder Company - Dynamites Series
Austin Powder Company - Emulex 500 and 700 Series
Austin Powder Company - Gelatin and Semi-Gelatin Dynamites
Austin Powder Company - Shock★Star Tubing
Bentonamit Expanding Grout
Bentonite Clay
Blastoff (for improvement of traction on rails)
Brass
Brazaloy (welding flux)
Bronze
Burke/EDOCO Acrylic Bondcrete CM-0170
Calibration Gases (for underground environmental measuring instrument calibration)
Carlon Standard Clear PVC Solvent Cement
Citra Scrub Cleaner
Clor-D-Tect 1000 (for analysis for chlorinated compounds used in oil)
Clor-D-Tect 4000 (for analysis for chlorinated compounds used in oil)
Concresive Liquid LPL (Part A and B) (for grouting rails to concrete inverts)
Concrete
Copper/Copper Wire
CRC Extreme Duty Silicon
Crosslinked Polyethylene Backer Rod

Delvo Stabilizer, set retarder admixture for concrete
Detacord – 18 grain Detonating Cord
Detonation Cord – 200 grain
DYNO-Nobel Explosive - K622A
DYNO-Nobel IRESPLIT Semi-Gelatin Dynamite
DYNO-Nobel UNIGEL Semi-Gelatin Dynamite
Ensign-Bickford PRIMADET Non-Electric Delay Detonator Noiseless Lead-In-Line (NLIL)
Ensign-Bickford PRIMADET Non-Electric Delay Detonators (LP) Series
Ensign-Bickford PRIMADET Non-Electric Delay Detonators (MS) Series
Ensign-Bickford Shock Tube
Federal Cartridge Company Small Arms Primers
Firedam 150 Caulk
FRACT.AG Expanding Grout
Freon R-22 (Genetron 22 and Forane 22)
FX-250 rapid-setting mortar (powder and liquid)
Helium (Noble Gas)
ICI Explosives CORDTEX Detonating Cord
ICI Explosives EXEL Flexible Plastic Shock Tubes
ICI Explosives EXEL Lead-In Line instantaneous detonator
ICI Explosives EXEL LP Long Delay Detonator
ICI Explosives EXEL MS Short Delay detonator
ICI Explosives GELDYNE Semi-Gelatin Dynamite (cartridges)
ICI Explosives USA, Inc., "Magnum 65" Detonator Sensitive Emulsion Explosive
ICI Explosives USA, Inc., PRIMACORD Detonating Cords
ICI Explosives XACTEX Semi-Gelatin Dynamite (cartridges)
Iresplit D&D1
ITP Standard Backer Rod (including Hot Rod XL)
Kit 82-A1 (Scotchcast 4)
Kit 82-A2 (Scotchcast 4)
Krypton (Noble Gas)
LAMTEC Corporation Brand 3035 Facing Material
LAMTEC Corporation Brand WMP-30 Facing Material
LAMTEC Corporation Brand WMP-F Facing Material
Lithium Bromide (LiBr)
M28R metal magnetic particle weld-testing powder (iron)
MARKAL Paintstik "B" and "B 3/8" markers
Masterflow® 928 (for grouting rails to concrete inverts)
Melment F10 (Super Plasticizer for Shotcrete)
Midwest Fasteners, Inc., Product Code IHSP spindle fastener
Monobath 50-50 (a photographic developer/fixer)
Neon (Noble Gas)

Nitrogen Gas
Nonel Super LP Series Detonator
Owens-Corning Fiberglass Insulation (Duct Wrap, PinkPlus®)
Plastiment Liquid, water-reducer/retarder admixture for concrete
Polyheed, cement dispersing agent
POWERCORD 60-, 100-, 150-, 200-grain Detonating cords
PVC
R-12 (Forane), Food Freezant 12
Rheobuild 1000, cement dispersing agent
Rheobuild 2500, cement dispersing agent
Rockbolts
Rolled channel arches (steel)
Sanford "Mean Streak" Waterproof Marking Sticks
Sherwin-Williams Co. KRYLON Interior/Exterior Spray Paint
Sika AEA-15, air admixture for concrete
Sikacrete 950, silica-fume admixture for concrete
Sikacrete 950DP, densified dry powder microsilica admixture for concrete
Sikament 86, water-reducing liquid admixture for concrete
Sikament 300, water-reducing liquid admixture for concrete
SikaTard 902/908/914, set retarder admixture for concrete
Silica Flour
Silica Sand
Stay-Silv 400023 brazing flux
Steel
Steel lagging
Steel sets
Sulfur Hexafluoride (SF6)
Super Filter Coat No. 412
SUVA-COLD MP® (tetra fluoroethane)
TD 210 rubber insulating compound
Tremproof waterproofing
Unigel
Weld-Aid Tip Dip - 006 Nozzle Gel
Welding Gases
Well-Guard drilling lubricant
White & Wib Hi Performance Acrylic Paint
Wil-X Cement/Grout
Windex glass cleaner - blue
Wire mesh
Xenon (Noble Gas)

Group 2 **<u>Approved for use subject to special requirements and in accordance with the manufacturer's directions and precautions relative to application, storage, disposal, etc.</u>**

	Note
736 Multipurpose Clear Silicone	7
1275 Almaplex Industrial Lubricants	1
1607 Contact Cleaner	1,2
2001 Monolec Wire Rope Lubricant	1
3752 Almagard Vari-purpose Lubricant	1
3M 1606 Cable Cleaner and Degreaser	1
3M SCOTCH-WELD DP-190 Grey Epoxy Adhesive	7
3M Super 77 Spray Adhesive	1
605 Almasol Vari-purpose Gear Lubricant	1
607 Almasol Vari-purpose Gear Lubricant	1
A-55 Clean Fuel	4,13
Air Kontrol Filter Spray	1
Ansul "Foray" dry chemical fire suppression agent	4
Aqua Resin Clear with dye	1
AS-43 Anti-slip Non-skid Surface Coating (for use in the TTF)	7
ATF Dextron (automatic transmission fluid)	1
Batteries/Battery Acid	1
Bortz Paint Thinner	1
Burke Non-Ferrous, Non-Shrink Grout	7
Burrell Fibercrete	3
Burrell Shotcrete	3
Butyl rubber adhesive	7
CC-2 Preparation Kit (Cable Cleaner)	1
Chevron Soluble Oil HD (Machining Oil)	1
Chevron Special LS Diesel Fuel	4,13
Chlorides	5
Citgo C-500 Motor Oil, SAE 30	1
Citra Spray Paint Numbers 2124, 2125, 2133, 2137, 2143, 2148, 2155, 2156, 2163, 2169, 2171, 2175, 2178, 2182, 2183, 2187, 2190, and 2192	1
CITRIKLEEN (parts cleaner/degreaser)	1
Copper Sulfate (must be retained within reference electrodes)	
Cotronics epoxy resin w/ hardeners	7
Cotronics two component ceramic adhesive w/ thinners and hardeners	7
CP 601 S Elastometric Firestop	7
CRC Moly Lube	1
CRC Quick Clean	1
Cresset Crete-Lease 727 release agent	7

	Note
DAP 100% Silicone Rubber Sealant	7
DB-Series Oil	1
Devcon Sure Shot Super Epoxy Resin and Hardener	7
Devguard Industrial Gloss Enamel	7
Devguard Tank and Structural Primer	7
Diesel Fuel	4
Dow Corning 4 electrical insulating compound	7
Dow Corning plastic adhesive 739	7
Dow Corning Silicone Rubber Compounds (DOW CORNING 200(R) FLUID, 1000 CST)	7
Drive Train Fluid HD SAE 30	1
Drive Train Fluid HD SAE 50	1
Dura-Lith Grease EP NLGI 2	1
Ensign-Bickford PRIMADET non-electric detonators and lead-in lines	5
Epple 28 sealant	1
EPY500 Part A and EPY500 Part B - two part epoxy	7
EZ Mud Shale Stabilizer and Viscosifier (used inside SEAMIST liner)	7
FE-36 fire suppressant agent	4
Fibercrete, Quikcrete	3
Fiske Brothers Refining Co. Fiske No. 35 Soluble Oil (cutting oil)	1
Flowcable, powder admixture for cement grout	6
FM-200® (fire suppressant inside building at end of TTF AOD)	4
Foster 36-10, Weatherite Mastic (roof sealant)	1
FR-40 Fire Retardant Material (wood treatment)	4
FS 657 Fire Block	7
GE Silicones Silicone Rubber Compounds (SILGLAZE-II/SILGLAZE 2800,	7
Gear Compound EP ISO 220	1
Gear Compound EP ISO 320	1
GEM®	4
Greenlee-Textron Blue Gel Cable Pulling Compound	1
Hercules Real Tuff	1,7
Hercules TFE Tape	7
HILTI (CF 128) Filler Foam	7
HPS Shotcrete Accelerator	3
Hydraulic Oil AW ISO 46	1
ICI Explosives POWERsplit Detonator Sensitive Slurry Explosive (cartridges)	5
Intraplast N	7
ITW-Philadelphia Resins Corp. Ramset EPCON System Hardener Ceramic 6 formula	1
ITW-Philadelphia Resins Corp. Ramset EPCON System Resin Ceramic 6 formula	1
John Deere & Company Hy-Gard Transmission and Hydraulic Oil	1
Litton/Kester flux-cored solder wire	1

	Note
LO/LV RTV Clear Silicone	7
Lubrication Engineers 9200 Almasol Dry Film Lubricant	1
Lubrication Engineers, Inc., 608 Almagard Vari-Purpose Gear Lubricant	1
Macklanburg-Duncan POLYCEL Expanding Foam	7
Master Builder MicroAir - air entraining agent	7
Matheson Gas Products POLY-ETCH Active Sodium Solution	7
MB-QSL 100, liquid shotcrete accelerator	3
MB-SF, accelerator, silica-fume mineral admixture for concrete, shotcrete	3
Meyco Rockbolt and Anchor Grout, cement grout	6
Mollub-Alloy 777-2 lubrication grease	1
Monoammonium phosphate dry chemical fire suppression agent	4
National Floor Sweep	7
NC111 Three Plus Wireline Silicone Lubricant	7
NH Armaflex	7
Non-Ferrous Shrink Grout No. CM-0010	7
OmegaBond 101 Epoxy (Parts A and B) - two part epoxy	7
Option 1 (Relton) (water based metal working fluid)	1
Oatey Purple Primer	7
Para-Chem Southern, Inc. Kraloy PVC Pipe Cement	1
Plastics (Solid)	7
Pot-Pouri solution, in portable toilet units	1
Potato Starch (Organic Developer)	7
Rawlplug Co. Chem-stud Anchor Capsules	1
Rectorseal Corp. HURRICANE HOMER PVC Solvent Cement	5,7
RectorSeal® NO. 5®	7
RectorSeal® Teflon Tape	7
Redi Seal	7
Resbond 907GF-6 Adhesive	7
Rosco Fog Fluid/Rosco Smoke Simulation Fluid	7
RPM Heavy Duty Motor Oil SAE 15W-40	1
RPM Universal Gear Lube SAE 80W-90	1
RPM Universal Gear Lube SAE 85W-140	1
RTV Clear Silicone	7
Rust-Oleum paint, aerosol	1
S5Z Wil-X Cement Grout (B)	6
SAE 90, Chevron RPM Gear Oil (transmission oil)	1
Safety Kleen Corp. Safety-Kleen #6638 Premium Gold Solvent	1
Scotch Brand 1602 Insulating Sealer (red)	1
Scotchcast Brand Flame Retardant Compound	1
Scotchkote Brand Electrical Coating	1
Seymore Marking Paint, 16-657	1

	Note
Shellzone (R) All Season Antifreeze (ethylene and diethylene glycol)	1
Shot-Set 250, liquid accelerator	3
Sigunit L20 Liquid, shotcrete set accelerator	3
Sigunit NC Liquid, shotcrete set accelerator	3
Sigunit Powder, shotcrete set accelerator	3
Silicone Rubber Sealant	7
SikaTell 100, liquid shotcrete admixture	3
SikaTell 200, liquid shotcrete admixture	3
Silli-Soda-Crete Grout (including Type I/II cement, sodium silicate, and Pozzolith 100-XR dispersing agent)	6
Sodium Hypochlorite (Organic Developer)	7
Soldering Paste by Johnson Manufacturing Company	7
Stay-Clean 40028 (Lead Free) soldering flux	1,2
SUNISO 3GS, viscosity=150 (specially refined oil for air conditioning compressors)	1
Tactoo GPA-72 hi-temp construction adhesive	7
Tammsgrout Supreme	6
Tempil 2500 white paint (for painting the TTF Heated Drift bulkhead)	7
Thermo Trap	7
Tremgrout 747	6
Type HP Cleaner/Degreaser	1
United Duct Sealer	1
Versi-foam Systems 1, 15, 50 and 1.75 pcf Refillable Component A	7
Versi-foam Systems 1, 15, 50 and 1.75 pcf Refillable Component B	7
Visquene	7
Water (Non-potable and Chlorinated)	10
WELD-ON P-70 Primer for PVC and CPVC plastic pipe	7
Wood	7

Group 3 **Materials; approved for use only in ECRB Cross Drift Niche Studies**

	Note
2,3,4,5-Tetrafluorobenzoic Acid	8
2,3,4,6-Tetrafluorobenzoic Acid	8
2,3,4-Trifluorobenzoic Acid	8
2,3,6-Trifluorobenzoic Acid	8
2,3-Difluorobenzoic Acid	8
2,4,5-Trifluorobenzoic Acid	8
2,4,6-Trifluorobenzoic acid	8
2,4-Difluorobenzoic Acid	8

	Note
2,5-Difluorobenzoic Acid	8
2,6-Difluorobenzoic Acid	8
3,4,5-Trifluorobenzoic Acid	8
3,4-Difluorobenzoic Acid	8
3,5-Difluorobenzoic Acid	8
Acid Yellow #7 (Lissamine FF)	8
Amino G Acid	8
Argon	8
Calcium Bromide	8
Calcium Iodide	8
FD&C Blue No. 1	8
FD&C Red No. 40	8
FD&C Yellow No. 5	8
FD&C Yellow No. 6	8
Fluorescein	8
Fluorescent Microspheres	8
Helium	8
Krypton	8
Lithium Bromide	8
Magnesium Fluoride	8
Magnesium Iodide	8
Neon	8
Nitrogen	8
Pentafluorobenzoic Acid	8
Polystyrene Microspheres	8
Potassium Bromide	8
Potassium Fluoride	8
Potassium Iodide	8
Potato Starch (powdered)	8
Pyranine	8
Rhodamine B	8
Rhodamine WT	8
Sodium Bromide	8
Sodium Chloride	8
Sodium Fluoride	8
Sodium Hypochlorite	8
Sodium Iodide	8
Sodium Molybdate Dihydrate	8
Sodium Tungstate Dihydrate	8
Sulfo Rhodamine B	8

	Note
Sulfur Hexafluoride (gas)	8
SUVA COLD - MP	8
Xenon	8

Group 4 **Materials; approved for use only in TS Loop Niche Studies**

	Note
Amino G Acid	8
FD&C Blue No. 1 (food color)	8
FD&C Red No. 40 (food color)	8
FD&C Yellow No. 5 (food color)	8
FD&C Yellow No. 6 (food color)	8
Fluorescein	8
Lissamine (Acid Yellow 7)	8
Pyranine	8
Rhodamine B	8
Rhodamine B Sulfo	8
Rhodamine WT	8

Group 5 **Materials; approved for use only in TS Loop Alcove Slot Cut Studies**

	Note
2,3,4,5-Tetrafluorobenzoic Acid	11
2,3,4,6-Tetrafluorobenzoic Acid	11
2,3,4-Trifluorobenzoic Acid	11
2,3,6-Trifluorobenzoic Acid	11
2,3-Difluorobenzoic Acid	11
2,4,5-Trifluorobenzoic Acid	11
2,4,6-Trifluorobenzoic Acid	11
2,4-Difluorobenzoic Acid	11
2,5-Difluorobenzoic Acid	11
2,6-Difluorobenzoic Acid	11
3,4,5-Trifluorobenzoic Acid	11
3,4-Difluorobenzoic Acid	11
3,5-Difluorobenzoic Acid	11
Magnesium Fluoride	11
Magnesium Iodide	11
Pentafluorobenzoic Acid	11

	Note
Potassium Bromide	11
Potassium Fluoride	11
Potassium Iodide	11
Sodium Bromide	11
Sodium Chloride	11
Sodium Fluoride	11
Sodium Iodide	11

Group 6 **<u>Materials; approved for use in Alcove #1 water infiltration testing</u>**

	Note
Calcium Bromide	12
Calcium Iodide	12
FD&C Blue No. 1 (food color)	12
Fluorescein	12
Lithium Bromide (in concentrations up to 500 ppm)	12
Magnesium Fluoride	12
Pyranine	12
Rhodamine WT	12
Sodium Chloride	12
Sodium Iodide	12

Group 7 **<u>Materials; approved for use at Busted Butte</u>**

	Note
Bromine (Br)	9
Cerium (Ce)	9
Cerium (III) chloride heptahydrate	9
Cobalt (Co)	9
Cobalt chloride hexahydrate	9
Colloids (geothite, hematite, silica, and smectite)	9
Copper (Cu)	9
Europium (Eu)	9
Fluorescein, sodium derivative	9
Fluorescent microspheres (organic)	9
Fluoro- methyl- and fluoride-substituted benzoic acids	9
Indium (In)	9
Lithium (Li)	9

	Note
Magnesium Fluoride	9
Magnesium Iodide	9
Manganese chloride tetrahydrate	9
Meyco TCC 766	9
Molybdate (MoO4)	9
Molybdenum (Mo)	9
Neodymium (Nd)	9
Nickel (II) chloride hexahydrate	9
Nickel (Ni)	9
Nitrogen	9
Polyheed SG	9
Polystyrene spheres	9
Potassium Bromide	9
Potassium Fluoride	9
Potassium Iodide	9
Pyridone	9
Rheneate (ReO4)	9
Rhenium (Re)	9
Rhodamine WT	9
Samarium chloride hexahydrate	9
Scandium (Sc)	9
Selenate (SeO4)	9
Selenium (Se)	9
Sodium Bromide	9
Sodium Chloride	9
Sodium Fluoride	9
Sodium Iodide	9
Sodium molybdate dihydrate	9
Sodium perrhenate	9
Sodium tungstate dihydrate	9
Strontium (Sr)	9
Terraset B-1000 System (Part A and Part B)	9
Thorium (Th)	9
Titanium (Ti)	9
Tungsten (W)	9
Uranium or Uranium Oxide (U or UO2)	9
Vanadium (V)	9
Yitrium (Y)	9
Zinc (Zn)	9

ICN 01

Group 8 **Materials; approved for use in Alcove #8**

Tracer	Total quantity	Concentration
Lithium Bromide	1,000 gram	500 ppm
Calcium Chloride	2,000 gram	2,000 ppm
Potassium Fluoride	100 gram	50 ppm
Potassium Iodide	50 gram	10 ppm
2,3-Difluorobenzoic Acid	50 gram	50 ppm
2,4-Difluorobenzioc Acid	50 gram	50 ppm
2,5-Difluorobenzoic Acid	50 gram	50 ppm
2,6-Difluorobenzoic Acid	50 gram	50 ppm
3,4-Difluorobenzioc Acid	50 gram	50 ppm
3,5-Difluorobenzoic Acid	50 gram	50 ppm
2,3,4-Trifluorobenzoic Acid	50 gram	50 ppm
2,3,6-Trifluorobenzoic Acid	50 gram	50 ppm
2,4,5-Trifluorobenzoic Acid	50 gram	50 ppm
2,4,6-Trifluorobenzic Acid	50 gram	50 ppm
3,4,5-Trifluorobenzic Acid	50 gram	50 ppm
2,3,4,5-Tetrafluorobenzoic Acid	50 gram	50 ppm
Pentafluorobenzoic Acid	50 gram	50 ppm
FD&C Blue No. 1	20 gram	20 ppm
Sulpho Rhodamine B	10 gram	10 ppm
Fluorescein	10 gram	10 ppm
Pyranine	10 gram	10 ppm
Rhodamine WT	10 gram	10 ppm
Lactic Acid Sodium Salt	30 gram	100 ppm
Fluorescent Microspheres	1 Liter	

Group 9 **Materials; approved for use in ECRB Cross Drift Systematic Drilling Boreholes**

	Note
2,3,4,5-Tetrafluorobenzoic Acid	14
2,3,4-Trifluorobenzoic Acid	14
2,3,5,6-Tetrafluorobenzoic Acid	14
2,3,6-Trifluorobenzoic Acid	14
2,3-Difluorobenzoic Acid	14
2,4,5-Trifluorobenzoic Acid	14
2,4,6-Trifluorobenzoic Acid	14

	Note
2,4-Difluorobenzoic Acid	14
2,5-Difluorobenzoic Acid	14
2,6-Difluorobenzoic Acid	14
3,4-Difluorobenzoic Acid	14
3,5-Difluorobenzoic Acid	14
Acid Yellow #7 (Lissamine FF)	14
Amino G Acid	14

NOTES:

1. These materials have decomposition or combustion products that have the potential to interfere with site characterization testing (i.e., Chlorine and Carbon). Limiting storage underground or storing in fireproof cabinets are conventional practices that can be used to address this concern. Refer to DIE Requirement 5 for QA controls.

2. These materials react with water to form products such as hydrochloric acid and acetic acid. Hydrochloric acid could bias Chlorine-36 measurements. Limiting storage underground or storing in such a way as to limit contact with water are conventional practices that can be used to address this concern. Refer to DIE Requirement 5 for QA controls.

3. Refer to DIE Requirement 12 of CRWMS M&O (1999a) and DIE Requirement 10 of CRWMS M&O (2000a) for limits or constraints.

4. Refer to DIE Requirement 5 for limits or constraints.

5. The use of any materials containing chloride in the Subsurface ESF shall require TCO concurrence, with the exception of chlorinated water/ice used for drinking and hand wash purposes. (See DIE Requirement 8)

6. Refer to DIE Requirement 6 of CRWMS M&O (1999a) and DIE Requirement 4 of CRWMS M&O (2000a) for limits or constraints.

7. Remove these materials, to the extent practical, upon completion of testing or activity.

8. Refer to DIE Requirement 11 for limits or constraints.

9. Refer to DIE Requirement 12 for limits or constraints.

10. Refer to DIE Requirements 2, 3, and 8 for limits or constraints.

11. Refer to DIE Requirement 13 for limits or constraints.

12. Refer to DIE Requirement 16 for limits or constraints.

13. Refer to DIE Requirements 5 and 6, DIE Requirements 9 and 11 of CRWMS M&O (1999a), and DIE Requirements 7 and 9 of CRWMS M&O (2000a) for limits or constraints.

14. Refer to DIE Requirement 15 for limits or constraints.